MM

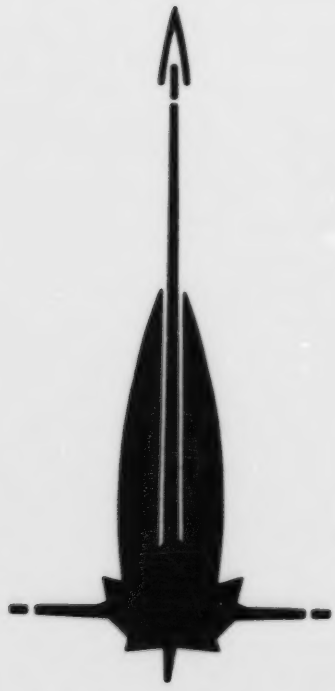
TP 4446E

german & milne inc.

AIR CUSHION ICEBREAKING BOW (ACIB)

TRIALS REPORT
1982/1983

CA1
DTC 801
83
A31
c.2



Montreal, Quebec
Ottawa, Ontario

TP 4446E

AIR CUSHION ICEBREAKING BOW (ACIB)

TRIALS REPORT
1982/1983

Prepared for:
Transportation Development Centre
Transport Canada
Montreal

by:
GERMAN & MILNE INC.,
Naval Architects and Marine Engineers
Montreal and Ottawa

July 1983

REPORT DOCUMENTATION FORM

1. Transport Canada Report No.	2. TDC Project No.	3. Recipient's Catalogue No.
TP4446E	4794	

4. Title and Subtitle	5. Report Date
AIR CUSHION ICEBREAKING BOW (ACIB) TRIALS REPORT 1982/83	July 1983 6. Performing Organization Report No.
7. Author(s)	8. Transport Canada File No.
J.A. Tarzwell, P. de L. Markham, C.W. Carter	D1460-163-14-6-2
9. Performing Organization Name and Address German and Milne Inc. 130 Slater Street, Suite 630 Ottawa, Ontario K1P 2R3	10. DSS File No. 10SD.T8200-2-2527 11. DSS or Transport Canada Contract No. OSD82-00128
12. Sponsoring Agency Name and Address Transportation Development Centre (TDC) 1000 Sherbrooke Street West Suite 2421 Montreal, Quebec H3A 2R3	13. Type of Report and Period Covered Final, Nov. 82 to June 83 14. Sponsoring Agency Code 4794
15. Supplementary Notes	16. TDC Project Officer J.E. Laframboise

17. Abstract

The Air Cushion Icebreaking Bow (ACIB), based at Thunder Bay, was overhauled and operated during the 1982/83 winter season. During the previous year of operation, a number of defects had been identified. These were corrected and the craft prepared for trials late in January 1983.

Trials were carried out with a tug, the 'Thunder Cape', and with a light icebreaker, the 'Alexander Henry'. While the mild winter precluded operation in thick ice, the ACIB/'Henry' combination broke ice 66 cm thick at speeds up to 6 knots.

The trials have yielded sufficient icebreaking performance data to permit evaluation of the ACIB performance with the 'Henry'. Among the findings was that mean ice-breaking speed of the ACIB/'Henry' combination was ten times greater than that of the 'Henry' operating alone. Trials with the tug indicated excellent manoeuvrability of the assembly. A number of modifications are recommended prior to its permanent use with the Canadian Coast Guard.

18. Key Words	19. Distribution Statement
Icebreaker, Air Cushion Icebreaker Bow, Air cushion platform, Thunder Bay.	Limited number of copies available from TDC.

20. Security Classification (of this report)	21. Security Classification (of this page)	22. No. of Pages	23. Price
Nil	Nil	98	-

TDC/CDT 79-005

FORMULE DE DOCUMENTATION POUR RAPPORT

1. N° du rapport Transports Canada	2. N° de l'étude — CDT	3. N° de catalogue du destinataire
TP4446E	4794	

4. Titre et sous-titre	5. Date du rapport
AIR CUSHION ICEBREAKING BOW (ACIB) Trials Report 1982/83	Juillet 1983
	6. N° du rapport de l'organisme exécutant

7. Auteur(s)	8. N° de dossier Transports Canada
J.A. Tarzwell, P. de L. Markham, C.W. Carter	DI460-163-14-6-2

9. Nom et adresse de l'organisme exécutant	10. N° de dossier — ASC
German and Milne Inc. 130 rue Slater, Suite 630 Ottawa, Ontario K1P 6E2	10SD.T8200-2-2527
	11. N° de contrat — ASC ou Transports Canada
	OSD82-00128

12. Nom et adresse de l'organisme parrain	13. Genre de rapport et période visée
Centre de développement des transports (CDT) 1000 ouest rue Sherbrooke Suite 2421 Montréal (Québec) H3A 2R3	Final, nov. 82 à juin 83
	14. Code de l'organisme parrain 4794

15. Remarques additionnelles	16. Agent de projet — CDT
	J.E. Laframboise

17. Résumé

La plate-forme brise-glace à coussin d'air (ACIB) basée à Thunder Bay a été réparée et utilisée au cours de l'hiver 1982/83. Les opérations de l'année précédente avaient permis d'identifier divers défauts qui ont été corrigés avant la mise en opération, fin janvier 1983.

Les opérations ont été exécutées avec un remorqueur, le 'Thunder Cape', et un brise-glace léger, le 'Alexander Henry'. L'hiver relativement doux n'a pas permis de briser des glaces très épaisses. Cependant, en conjonction avec le 'Henry', des glaces de 66 cm ont été rompues à une vitesse de l'ordre de 6 noeuds.

Ces essais ont fourni des données de comparaison avec le brise-glace en opération par lui-même. Ainsi la vitesse du 'Henry' avec la plate-forme à coussin d'air était d'environ dix fois celle du 'Henry' opérant par lui-même. D'autre part l'essai avec le remorqueur a démontré l'excellente manoeuvrabilité de l'ensemble. Le rapport fait aussi état d'un certain nombre de modifications qui pourraient être apportées au véhicule avant sa mise en opération permanente par la Garde côtière canadienne.

18. Mots-clés	19. Diffusion
Brise-glace, brise-glace à coussin d'air, plate-forme à coussin d'air, Thunder Bay	Le CDT dispose d'un nombre limité de copies.

20. Classification de sécurité (de ce rapport)	21. Classification de sécurité (de cette page)	22. Nombre de pages	23. Prix
Néant	Néant	98	-

CDT 7DC 79-005

PROJECT TEAM

The project team for German & Milne Inc. consisted of:

Philip Markham, Project Manager
John Tarzwell, Trials Manager
Craig Carter, Trials Engineer
Lawrence Sundell, Trials Technician
James Stirling
Abraham Benjamin
Barry Quart

Instrumentation Group, Montreal

ACKNOWLEDGEMENTS

German & Milne Inc. gratefully acknowledges the outstanding co-operation and response of its Sub-Contractors in these trials:

- Vulcan Machinery and Equipment Limited
- Rematech Industries, Division of Rubbertex Corporation Limited
- Western Engineering Service Limited

We also wish to thank particularly for their participation, advice and assistance:

- Captain John McDonald, the officers and crew of the CCG ALEXANDER HENRY
- Messrs. J. Leddy, of Vulcan, and M. T. Skinner, of Rematech
- Messrs. E. Gerow and J. Hansen, of the Canadian Coast Guard, who were seconded to the ACIB for the trials
- Messrs. N. E. Rudback, of TDC, and M. A. Ball and R. G. Wade, of CCG
- Capt. G. Stieh, CCG Sub-Base Thunder Bay
- Mr. J. Luck and Captain M. Keeling (THUNDER CAPE), of Western
- Mr. H. Fowler, of the National Research Council of Canada
- Mr. D. Gariépy, of Supply & Services Canada, the Science Procurement Manager

and, of course,

- Mr. J. Laframboise, of TDC, the Scientific Authority

SUMMARY

The Canadian Coast Guard air cushion icebreaking bow (ACIB) was transported to Thunder Bay in 1981, where it was erected. Brief and inconclusive trials were carried out late in the ice season and a number of deficiencies were revealed.

Late in 1982, a second trials program was started, consisting of an extensive series of repairs and modifications, followed by testing with a small vessel, the tug THUNDER CAPE, and a larger vessel, the light icebreaker ALEXANDER HENRY.

The mild winter could hardly be considered typical for Thunder Bay, but ice thicknesses up to 66 cm (26 in), as well as ridges of much greater thickness, were broken successfully, proceeding continuously at speeds up to 6 knots. The tug/ACIB combination was particularly impressive, and very tight turns were possible. Satisfactory data were obtained, as well as "hands-on" operational experience for CCG personnel.

It is considered that the icebreaking capability of the ACIB has been demonstrated, together with markedly reduced fuel consumption and time required to open channels. The elimination of the ramming operation reduces considerably the wear and damage to the hull and propulsion system, and there was a noticeable reduction in propeller ice strikes.

During the trials, problems were encountered with skirt segments, with the fan drive clutches and with the hydraulic system. All other systems performed satisfactorily. It is considered that fixes for all perceived problems can now be applied, and that a reliable craft can be provided for future operations.

SOMMAIRE

En 1981, la plate-forme à coussin d'air utilsée comme engin de déglaçage par la Garde côtière canadienne (GCC) avait été transportée à Thunder Bay, mise en place et soumise à des essais vers la fin de la saison des glaces. Bien que brefs et non concluants, ces essais ont révélé un certain nombre de faiblesses de la plate-forme.

Vers la fin de 1982, un deuxième programme d'essais a été lancé comportant d'importants travaux de réparation et de modification de la plate-forme, suivis d'essais pour lesquels celle-ci a été couplée, d'abord à un remorqueur, le THUNDER CAPE, et ensuite à un brise-glace léger, le ALEXANDER HENRY.

Malgré la douceur anormale de l'hiver 1982/1983 dans cette région, les navires équipés de la plate-forme ont dû affronter des glaces dont l'épaisseur atteignait 66 cm (26 po) et des crêtes de plus grande épaisseur encore; toutefois ils ont pu les briser sans problème, tout en avançant à des vitesses de l'ordre de 6 noeuds. L'ensemble remorqueur/plate-forme a été particulièrement efficace et s'est montré capable d'effectuer des virages très serrés. Une grande quantité de données très utiles a pu être recueillie et une expérience opérationelle acquise par les membres de la GCC.

L'aptitude de la plate-forme à briser les glaces a été de la sorte mise en évidence, ainsi que les économies de carburant et de temps de manoeuvre qu'elle permet. En outre, le fait de ne plus avoir à charger les glaces s'est répercuté favorablement sur le taux d'usure et d'avarie de la coque et du système propulsif du navire équipé de la plate-forme, d'autant plus que le nombre de heurts de l'hélice contre les glaces a sensiblement diminué.

Les secteurs où des problèmes ont subsisté sont les segments de jupe, les mécanismes d'embrayage des ventilateurs et le système hydraulique. Tous les autres systèmes ont bien fonctionné. La solution de ces problèmes étant connue, il peut être affirmé que la plate-forme constitue désormais un engin de déglaçage fiable.

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	NARRATIVE REPORT	2
	2.1 Summary	2
	2.2 Essential Repairs and Modifications	6
	2.2.1 Requirement	6
	2.2.2 Sub-Contract	6
	2.2.3 Schedule	7
	2.2.4 Repairs and Modifications	7
	2.2.4.1 Notch Structure	8
	2.2.4.2 Skirt Segments	13
	2.2.4.3 Spray Aprons	15
	2.2.4.4 Ballast Tanks	15
	2.2.4.5 Electrical	16
	2.2.4.6 Control Room	17
	2.2.4.7 Fans	18
	2.2.4.8 Hydraulics	18
	2.2.4.9 Winches	21
	2.2.4.10 Engines	22
	2.2.4.11 Instruments	22
	2.2.4.12 Miscellaneous Structural Work	23
	2.2.4.13 Safety Equipment	24
	2.3 Test Instrumentation	24
	2.3.1 Requirement	24
	2.3.2 ACIB Instrumentation	25
	2.3.3 Ship Instrumentation	28
	2.3.4 Ice Conditions	29
	2.3.5 Environmental Data	30
	2.4 Initial Tests - Unnotched	30
	2.4.1 Functional Tests	30
	2.4.2 Tests Over Land	31
	2.4.3 Launch	32
	2.4.4 Port Colborne Fairleads	33
	2.4.5 Checkout Over Water	33

			Page
2.5	**Tests with Tug THUNDER CAPE**		35
	2.5.1	Arrangements	35
	2.5.2	Preparations	36
	2.5.3	Icebreaking Tests	37
	2.5.4	Post-Test Observations and Inspection	39
2.6	**Tests with CCGS ALEXANDER HENRY**		41
	2.6.1	Initial Notching and Functional Tests	41
	2.6.2	Performance Trials	43
		2.6.2.1 Objectives	43
		2.6.2.2 Preparations	44
		2.6.2.3 Trial Runs	45
	2.6.3	Inspection	47
	2.6.4	Fuel Consumption - ALEXANDER HENRY Alone	49
2.7	**Repairs and Modifications**		50
2.8	**Operational Trials with CCGS ALEXANDER HENRY**		54
	2.8.1	Operations Alone	54
	2.8.2	Trials Objectives	55
	2.8.3	Hover Tests	55
	2.8.4	Heavy Weight Operations	55
	2.8.5	Light Weight Operations	57
	2.8.6	Post-Test Inspection and Repairs	59
	2.8.7	Icebreaking Demonstration	62
	2.8.8	Open Water Trials	62
2.9	**Lay-Up**		63
	2.9.1	Termination	63
	2.9.2	Beaching Operation	63
	2.9.3	Inspection	63
	2.9.4	Close Out	65
3.0	**PERFORMANCE PARAMETERS**		66
3.1	**Introduction**		66
3.2	**Test Results**		70
	3.2.1	Test Objectives	70
	3.2.2	Shaft RPM Versus Speed	70
	3.2.3	Path Width and Piece Size	75
	3.2.4	Turning Radius	77

			Page
	3.2.5	Trim Angle Versus Speed	77
	3.2.6	Fuel Consumption	79
	3.2.7	Open Water Trials	79
	3.2.8	Static Hover Tests	82
	3.2.9	Freeboard Versus Ballast	82
	3.2.10	Shaft RPM	83
3.3	**Technical Observations**		85
	3.3.1	Electrical System	85
	3.3.2	Hydraulic System	86
	3.3.3	Liquid Ballast	86
	3.3.4	Icing	87
	3.3.5	Skirt	87
	3.3.6	Handling	89
3.4	**An ACIB for Arctic Ice**		89
4.0	**CONCLUSIONS AND RECOMMENDATIONS**		91
4.1	**Conclusions**		91
4.2	**Recommendations**		93
5.0	**PROPOSAL FOR FOLLOW-ON PROGRAM**		94

LIST OF FIGURES AND TABLES

		Page
Figure 1	Notch Segment and Skirt Pan Attachment	8
Figure 2	Notch Frame Extension	10
Figure 3	Pushing Post Timbers	10
Figure 4	Skirt Rod Support Brackets	14
Figure 5	Ballast Tank Enclosure	14
Figure 6	Winch Brake Modification	20
Figure 7	Inspection Hatch	20
Figure 8	Underdeck Video Camera Mount	26
Figure 9	Video Camera Installation for Speed Measurements	26
Figure 10	Port Colborne Fairlead	34
Figure 11	Work on the THUNDER CAPE's Bow	34
Figure 12	Inflated Notch Segments	42
Figure 13	Airborne View of the ACIB/ALEXANDER HENRY	48
Figure 14	Closed Sole Modification	48
Figure 15	Tracks of Performance Trial Runs	68
Figure 16	Tracks of Operational Trial Runs	69
Figure 17	Underdeck Video Camera Coverage	73
Figure 18	ACIB/THUNDER CAPE Turning Circle	74
Figure 19	Pattern of Initial Breaking of 66 cm Ice	76
Figure 20	ACIB/ALEXANDER HENRY Bow Wave in Open Water	80
Figure 21	RPM Records, ACIB/ALEXANDER HENRY	84
Figure 22	RPM Records, ALEXANDER HENRY Alone	85

Table 1	Summary of Events	67
Table 2	Icebreaking Performance Summary	71
Table 3	Fuel Consumption versus Speed - 1 February 1983	78
Table 4	Average Fuel Consumption	78
Table 5	Open Water Trials - Test Results	80
Table 6	Static Hover Tests	81
Table 7	Freeboard Versus Ballast Weight	82

APPENDICES

A INSTALLATION OF RPM MONITORING SYSTEM

B INVESTIGATION OF BOND FAILURES

C TEST PLAN 1982/83

ACIB/THUNDER CAPE COMBINATION UNDER WAY IN ICE

1.0 INTRODUCTION

For the past decade, Transport Canada has been actively developing air cushion icebreaking technology in order to explore the technical, economic and commercial implications of this innovative icebreaking phenomenon.

Full-scale testing with an icebreaking bow platform was first carried out at Thunder Bay in 1975/76. The air cushion vehicle used was a 100 ton capacity Arctic transporter (ACT-100) provided by Arctic Systems Ltd. The ACT-100 air cushion platform was modified to fit the bow of CCGS ALEXANDER HENRY. Compared to her normal performance, the icebreaker with the air cushion platform attached was able not only to break substantially thicker ice, but did it while progressing at higher speeds, using much less fuel and leaving a wider track for other ships to follow.

A second series of full-scale tests was undertaken during the winter of 1976/77. The object of these tests was to demonstrate the commercial application of the air cushion platform, and to accumulate additional data on its capability under operational conditions with commercial type vessels. The technique for the demonstration was to use the commercial tug THUNDER CAPE or the CCGS GRIFFON to push the ACT-100 air cushion icebreaking platform to a vessel requiring a temporary icebreaking assistance. During the trial, the commercial vessel IMPERIAL ST. CLAIR was assisted in this manner. In addition, the ACV was attached to the bow of the ST. CLAIR to demonstrate the feasibility of such an operation. These trials showed a threefold improvement in the icebreaking capability of the combination ship and ACIB over that of the icebreaker operating alone.

In 1979, the Canadian Coast Guard contracted for a purpose designed Air Cushion Icebreaking Bow (ACIB) to be built by Hoverlift Systems Limited (HSL) in Calgary. When Hoverlift Systems were unable to deliver the ACIB to Transport Canada in fully operating condition, as required by their contract, the Transportation Development Centre (TDC) was tasked by Coast Guard to prepare the craft for testing and carry out initial tests of the design.

In the Fall of 1981, the ACIB was moved from Calgary to Thunder Bay, the site of the earlier ACT-100 trials. The craft was completed and limited tests were carried out late in the 1981/82 winter season. These tests achieved a performance which was, in some respects, similar to that of the earlier icebreaking platform. They also identified a number of design deficiencies which required correction prior to further testing.

In order to complete the evaluation, and to explore the full operating envelope of the ACIB, it was planned to carry out certain essential repairs and modifications to the craft and to conduct a further test program over varying ice thicknesses, using one or more host ships, during the 1982/83 winter season. The proposed plan of action was to select a prime contractor for the evaluation, who would be responsible for the establishment of a test plan, the implementation of the essential repairs and modification of the ACIB, the day-to-day maintenance and operation of the craft, the direction of the trials (in co-operation with TDC and the Canadian Coast Guard), the collection of data, the analysis of test results (including extrapolation of these results to describe an ACIB suitable for use in the Arctic), and the preparation of reports.

Supply & Services Canada Request for Proposal 10SD-T8200-2-2527, dated 16 September 1982, solicited proposals for the implementation and management of the 1982/83 evaluation of the Air Cushion Icebreaker (ACIB) on behalf of the Transportation Development Centre and, on 22 November 1982, a contract was awarded to German & Milne Inc.

The objectives of the 1982/83 trials were:

1) To explore and define, in quantitative terms, the performance parameters of the ACIB.

2) To gain operational experience with the ACIB to the greatest extent practical during the 1982/83 winter season.

The report which follows presents a narrative account of the trials, a summary of the performance parameters as measured, conclusions and recommendations.

2.0 NARRATIVE REPORT

2.1 SUMMARY

This narrative report is presented in some detail in order to make it quite clear that a great deal of work and improvisation went into the 1982/83 trials because of the circumstances under which they were conducted.

The 1981/82 trials were carried out under environmental conditions which are very unlikely to be encountered in a properly planned ice management program. Inconclusive results were obtained in very flexible ice and consequently the potential of the ACIB was not revealed. Thus the 1982/83 ice management program for Thunder Bay district was planned as usual, assuming a conventional operation using the CCGS ALEXANDER HENRY, with use to be made of the ACIB on an availability basis. It was not appreciated by any of the participants that since the ACIB/ALEXANDER HENRY combination would break ice at a much greater rate than that achieved by the ALEXANDER HENRY alone, acceptable down-time could take on a different meaning. As a consequence during the trials, too much emphasis was placed on every day availability of the ACIB and additional cost was incurred as a result in rushed and overtime work. However, the objectives of the trials were met.

It is hoped that the ice management program for Thunder Bay District in the 1983/84 season will be planned around an ACIB/small vessel combination, with the ALEXANDER HENRY for emergency back-up only.

The narrative may be summarized as follows:

1. A very extensive program of repairs and modifications was carried out and initial, unnotched tests completed by mid-January. That this was possible was due entirely to very mild weather and to the enthusiastic commitment of Vulcan Machinery & Equipment and Rematech Industries to the project. No significant difficulties were encountered except with the hydraulic system control valves and winch brakes and, in general, the design changes, principally in the notch area and to the attachments of the skirt segments, were very successful. Hover testing over land produced the expected heave instability, but the craft

performed satisfactorily over water, and the absence of major air leaks and the smooth inflation of the notch segments was apparent.

2. Tests with the tug THUNDER CAPE exceeded expectations. Removal and fairing of bumpers and protrusions on the bow of the tug was satisfactory, and notching was quite straightforward. However, some minor damage was incurred which could be avoided another time. The actual icebreaking, which was performed in 30-35 cm of ice was entirely successful, and a continuous speed of 5.4 knots was achieved. The manoeuvrability (a turning circle of 25 m radius) was exceptional.

3. Tests with the CCGS ALEXANDER HENRY also went very well, no difficulty being experienced with notching, and continuous speeds up to 6 knots achieved in ice thicknesses up to 66 cm. During this period performance measurements were made which are summarized in Section 3.0.

4. During the tests, extensive damage was incurred to skirt segment sole plates. These plates were designed to prevent entry of ice pieces into the segments when travelling in a direction such that the inboard edge of the segment is leading, that is, when the segment can scoop up ice or water. They consist of a piece of material closing the inboard face of each segment, except for a flap at the bottom, which folds over the open, scooping edge of the segment when the flow is outward. They worked satisfactorily as intended on the aft segments but on the forward sections, where the flaps are trailing in forward motion, the flaps became trapped between ice pieces and the sole plates were damaged or torn off. Some consideration was given to operating without carrying out repairs. However, as the ALEXANDER HENRY was due for a self-refit program, it was decided to modify the sole plates and repair all damage. During tests after this repair work, the port engine fan drive clutch failed catastrophically and had to be replaced.

2.1 **SUMMARY** (Cont'd)

5. Operational trials with the ALEXANDER HENRY were carried out successfully by a Coast Guard crew who had no difficulty with the operation or handling of the ACIB. The icebreaking performance of the combination was impressive, particularly in terms of the rate at which ice was broken, the elimination of the necessity for ramming, and the reduction in the number and severity of propeller ice strikes. Damage to sole plates recurred during this phase and was attributed to poor bonding and some poor workmanship resulting from rushed work. Subsequent investigation has shown that curing is arrested under freezing conditions, and it is probable that no new bonds were given sufficient time inside the shops to cure properly. In spite of the damage, the ACIB was available and used successfully to break ice as long as it was required.

6. Following the operational trials, the craft was beached on a pad formed from the ballast blocks and decommissioned to a caretaking status pending decisions regarding its future.

2.2 ESSENTIAL REPAIRS AND MODIFICATIONS

2.2.1 Requirements

As required by the ACIB Implementation and Management Contract, only those repairs and modifications essential to the achievement of the 1982/83 evaluation were to be made to the craft. The information provided in the Request for Proposal included a list of some 75 suggested changes and repairs. Because of the constraints of time and funding, a judicious selection of those that were essential and achievable had to be made. This was done following a preliminary inspection of the craft under the terms of TDC contract D1460-163-14-7 which was set up for the purpose. The results of the preliminary inspection were tabled at a meeting of TDC, CCG and German & Milne representatives on 1 November 1982 and the list of essential repairs and modifications endorsed.

2.2.2 Sub-Contract

It was accepted by the Contract Authority that German & Milne would sub-contract the repair and modification work to a company located in Thunder Bay.

Because of the time constraints, the selected sub-contractor would have to be very responsive and well equipped to carry out the required work. The schedule of activities given in the Implementation and Management Contract allowed only a 6-week period from 1 November to 15 December 1982 for completion of the repairs and modifications to the ACIB. Because of their prior involvement with the ACIB and their sound reputation for responsiveness and quality workmanship, Vulcan Machinery and Equipment Ltd. was selected as the Sub-Contractor.

Immediately the main contract was let, a sub-contract with Vulcan was negotiated. The Statement of Work for this sub-contract was based on the following source documents:

- DSS RFP 10SD.T8200-2-2527, Reference 4, Section 4;
- DSS Contract 0SD82-00128, Appendix A, Annex 1;

2.2.2 **Sub-Contract** (Cont'd)

- o G&M Report No. 7020-R-02, Appendix A;
- o TDC Memos, D1460-163-14-2 of 12 May 1982 and 3 August 1982; and
- o Various amended Bell Aerospace and Hoverlift Systems drawings.

A copy of these source documents and other reference material is provided under separate cover.

2.2.3 **Schedule**

As the main contract was not signed until 22 November 1982, work could not commence until that date. This further compressed the already tight schedule and it was necessary to slip the target date for completion of the work to 31 December 1982. Subsequent additional authorized modifications and unforeseen repairs necessitated a further slippage to 15 January 1983. This, however, did not adversely affect the test program which followed.

The accomplishment of the large amount of work entailed in an elapsed time of 8 weeks was a tribute to Vulcan's responsiveness and competence, particularly in view of the fact that much of the work had to be done on the craft in an exposed location under adverse weather conditions.

2.2.4 **Repairs and Modifications**

A description of the work accomplished under the sub-contract with Vulcan follows.

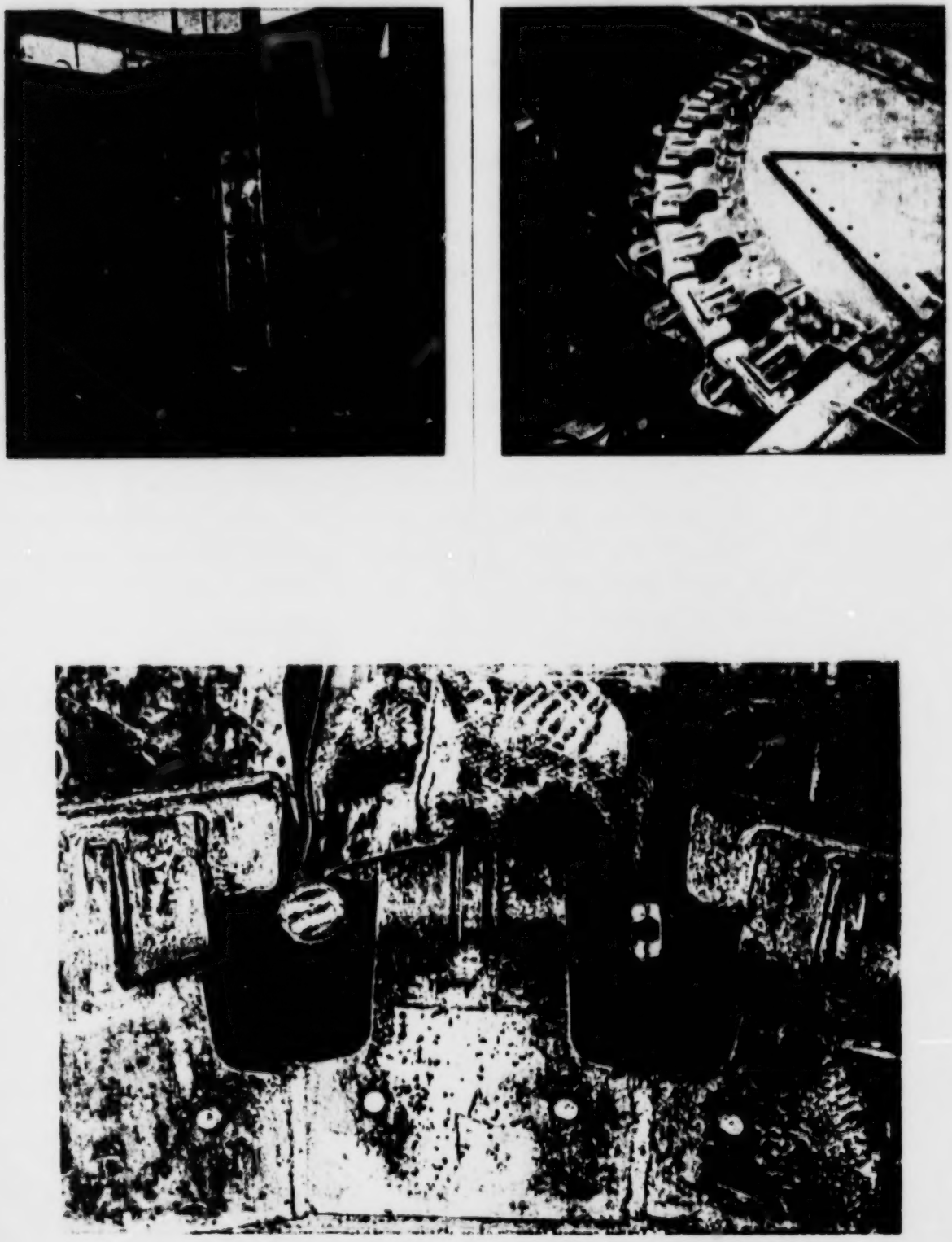


FIGURE 1: Notch Segment and Skirt Pan Attachment

2.2.4.1 NOTCH STRUCTURE

The objectives of the notch structure modifications were:

a) To strengthen the attachment of the notch frames to the carousel while retaining the capability of disconnecting the notch segments and frames for repairs;

b) To dispense with the need for saddles to contain the notch segments and transfer the lifting load to the notch frames;

c) To dispense with the need for nets and weights to hold down the outboard ends of the segments when inflated; and

d) To improve the effectiveness of the notch spray aprons.

These improvements were achieved as follows:

Frame Attachment: In the original configuration, the skirt pan, frame and notch segment were removed as a unit by sliding the skirt pan upwards out of engagement with the vertical retaining rods attached to the carousel. In the modified version, the skirt pan would be fastened to the carousel and the notch segment secured to the skirt pan by means of a rod inserted in loops in the end of the segment and secured in the narrow space between the adjacent skirt pans, as shown in Figure 1. Removal of the frames would be achieved by removing their 3.8 cm diameter hinge pins.

The modification was accomplished by:

- removing and discarding the notch segment retaining frame attached to the skirt pan;

- removing and discarding the skirt pan supporting rods attached to the carousel;

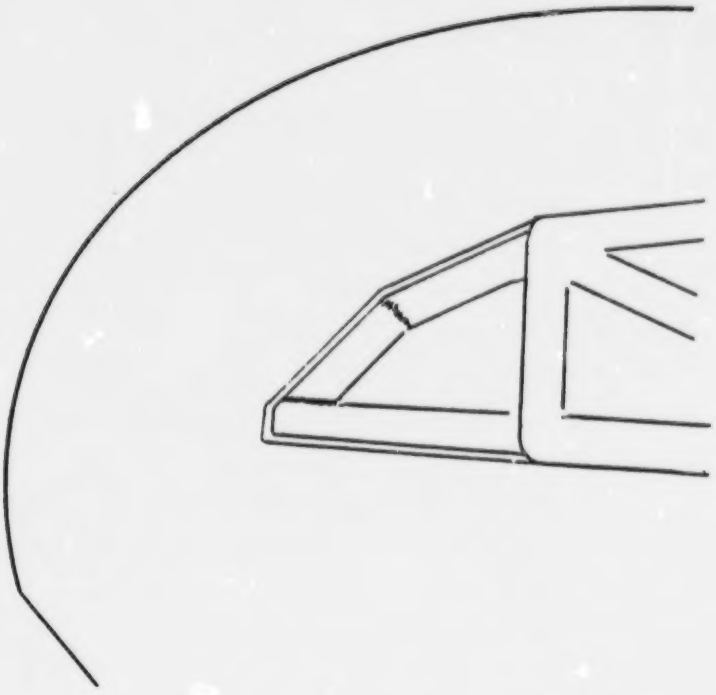


FIGURE 2: Notch Frame Extension

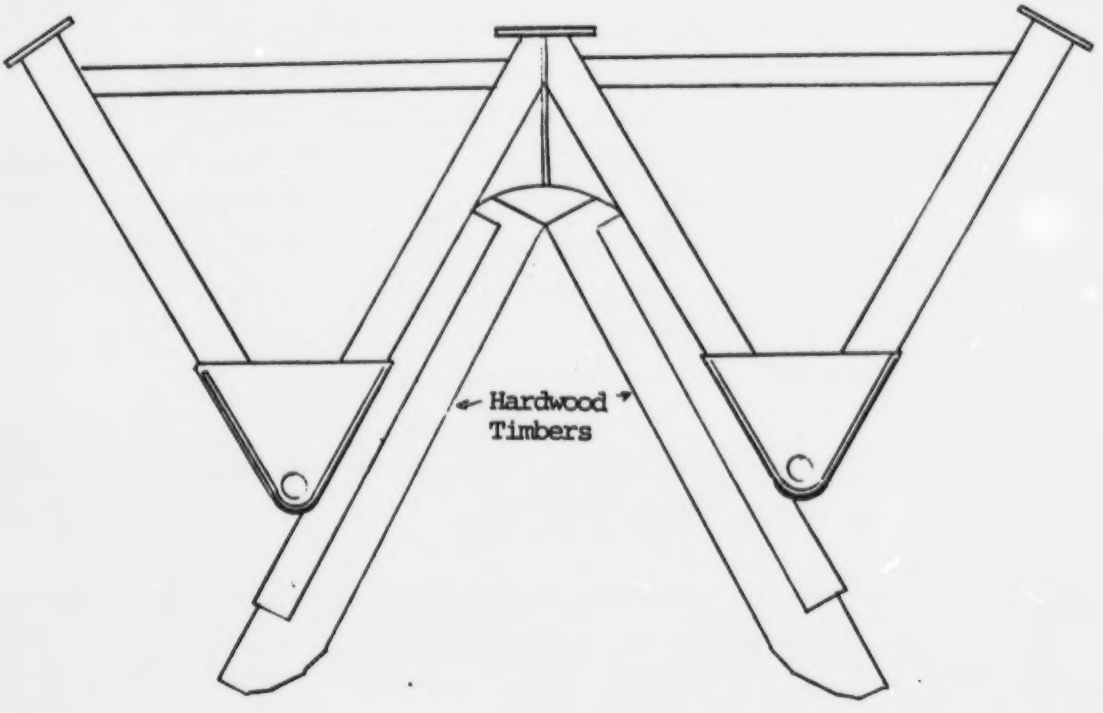


FIGURE 3: Pushing Post Timbers

2.2.4.1 NOTCH STRUCTURE (Cont'd)

- o fabricating and welding in place a support bracket for the top end of the skirt pan.

- o welding the lower end of the skirt pan to an extended shelf at the base of the carousel.

Note: The shelf extension was required to permit the skirt pan to be relocated approximately 5 cm further outboard from the carousel to provide the needed space between the skirt pans for insertion of the segment loops.

Frame Extension: To achieve objectives (b) and (c) above, a frame extension as shown in Figure 2 was required to permit the anchoring of the notch segment along a quadrant following the natural curve of the outboard portion of the segment. The required extension was fabricated and welded to each of the eight notch frames.

Segment-to-Frame Attachment: As a further step in achieving objectives (b) and (c), the nuts, bolts and short battens used to attach the notch segments to the frames were replaced by studs installed in a mounting plate extending the full length of the frame (except for the hinged portion of Frames 4 and 5) and battens extending the full length of the straight portion of the frames. Separate battens were provided for the curved extension to the frame. Additionally, provisions were made for attaching both sides of the notch segments to adjacent frames. Previously, only one side was attached making saddles necessary.

Notch Segment Modifications: As mentioned previously, the segments were fitted with loops at their inboard end to accommodate the securing rods as shown in Figure 1. Additionally, a hood was attached to the inboard end to cover the skirt pan upper attachment bracket and D-rings were installed on notch segments 4 and 5 for attachment of the wear aprons.

2.2.4.1 NOTCH STRUCTURE (Cont'd)

Notch Segment Repairs: Previously punched holes were covered and damage to the segments and their respective sole pieces was repaired. Anti-snag sole flaps were checked for proper length and extended where necessary. Doubling strips were added between the reinforcing straps in the segments in the area of the frame attachment battens to provide a uniform thickness of material in this area.

Notch Saddles: These were removed and stored for possible future use or as material for other uses.

Side Walls: Side wall extensions were fabricated and installed to accommodate the extended length of the segment attachment strip. Segment attachment studs in the same pattern as those on the frames were installed in mounting plates which were welded to the side wall and side wall extensions along a line matching that of the segment attachment studs on the notch frames. Additionally, a 15 cm triangular hole at the outboard extremity of the sidewall was capped to prevent air leakage.

Notch Spray Apron: A new section was added to the notch spray aprons to extend them into the notch opening. The extensions were attached by D-rings and shackles to the wear aprons and to the adjacent notch segments. The lower end of the spray apron extensions were attached by D-rings, schackles and chains which extended inboard to attachment points on the pushing post. Similar attachments were made to the D-rings installed for this purpose on the bottom of the side wall extensions.

Netting and Chain Weights: These were removed and stored.

2.2.4.1 NOTCH STRUCTURE (Cont'd)

Notch Rollers: The notch roller assembly was removed for inspection and repair. The inspection revealed that in prior use, the rollers had not pivotted into position for proper contact with the pushing ship's bow, and extensive wear on the inboard end of the roller support frame and the roller itself had occurred. Further, the rubber portion of the rollers had separated from their tubular steel cores. A modification of the roller support assembly which would provide increased pivotal movement and fabrication of new rollers was considered. However, because of time and budgeting considerations, it was decided to replace the rollers with wooden scrubbing blocks attached to the pushing assembly yoke as shown in Figure 3.

2.2.4.2 SKIRT SEGMENTS

Segment Supports: The ACIB design specification called for a capability of replacing skirt segments over water. Prior experience with the as-built skirt support system showed that this was impractical. Alternative configurations which would achieve this requirement were considered by TDC, however, the practicality of the concept of emergency replacement of skirts over water (ice) in sub-zero weather conditions was brought into question. Considering the perceived difficulty of meeting this requirement and the time constraints of the program, the requirement was waived.

The main weakness of the as-built configuration centered around the T-piece mid-point suspension bracket for the segment support rod. Ice snagging of the skirt or the blow-out of an adjacent skirt segment could cause the support rod to come out of engagement with the T-piece. With the rod unsupported at its mid point, it could buckle and pull out of its end supports causing a catastrophic blow-out of the segment. To overcome this problem, a mid-point support bracket which would ensure positive retention of the support rod was designed, fabricated and installed. See Figure 4.

As an additional precaution against the support rod coming out of engagement, a safety pin was installed in the lock pin which secures the rod to its outboard support bracket.

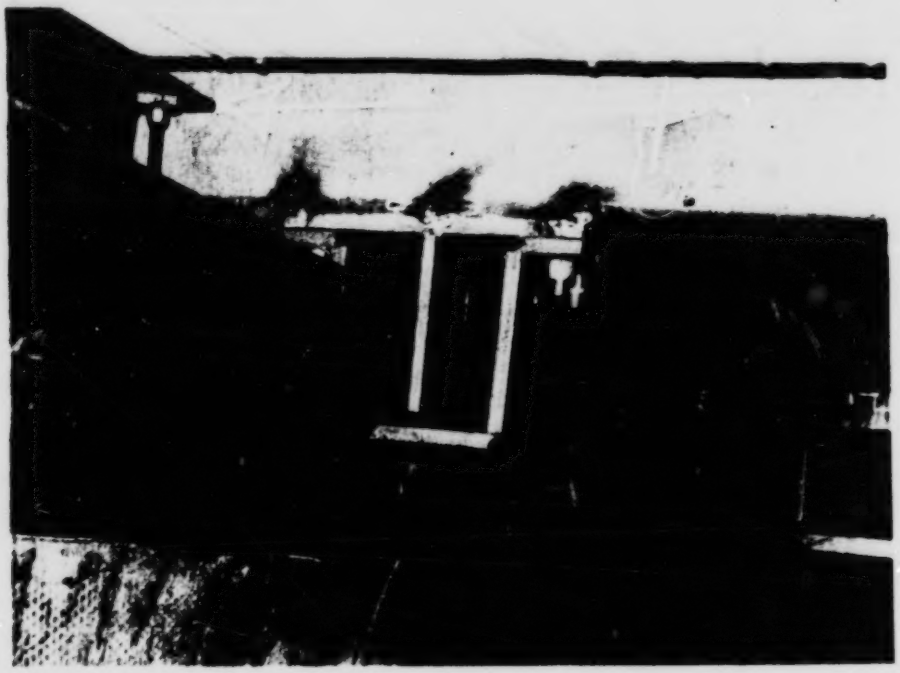


FIGURE 4: Skirt Rod Support Brackets

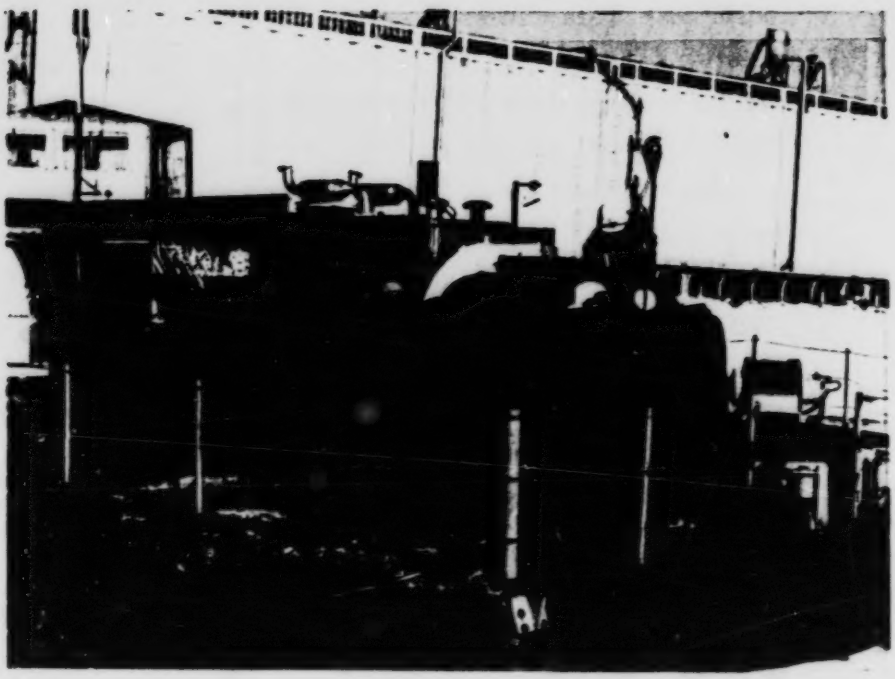


FIGURE 5: Ballast Tank Enclosure

2.2.4.2 SKIRT SEGMENTS (Cont'd)

Segment Sole Pieces: Experience gained during the 1982 trials showed that the segments in the forward section of the craft should be fitted with a closed face (sole piece) and an anti-snag flap to prevent them from snagging on broken ice during backing manoeuvres. Such sole pieces had been installed previously on the aft section segments to prevent their snagging during forward motion. It was therefore decided to install similar item in the forward section segments. (Ref.: Hoverlift Drwgs. 500-94-024 and 500-94-036). To accomplish this and to make needed repairs to the skirt segments and the underdeck structure, all skirt segments were removed, repaired, modified and replaced.

2.2.4.3 SPRAY APRONS

The spray aprons were removed for access to the skirts and other underdeck components. Prior to replacement, the notch extension piece mentioned above was added and all nuts and bolts connecting the various sections of the apron removed and reassembled with penny washers to improve the clamping action. Additionally, the gap between the top of the apron and the deck structure was reduced by deleting the original 6 chain links between the two attachment shackles. The latter were lockwired to ensure against their working loose in operation.

2.2.4.4 BALLAST TANKS

The HSL533 ACIB has four stability conditions:

a) Over land, hovering;
b) Over water, floating;
c) Over water, hovering alone;
d) Over water, hovering attached to a ship.

2.2.4.4 BALLAST TANKS (Cont'd)

The solid ballasting could not be used to provide trimming for conditions (c) and (d), therefore, water ballast tanks had been added for the 1982 trials. For the 1983 trials, it remained to provide a means of preventing the water ballast from freezing. Consideration was given to insulating the tanks and fitting them with electric immersion heaters, however, this was not feasible at the time because adequate electric power was not available on the craft. As an alternative, the tanks were enclosed with a canvas covered metal frame and heated air ducted into the space between the tank and the canvas cover from an oil fired heater. Two heaters were purchased for this purpose - one being a back-up for the other. The heaters provided were Anthes Frost Fighters, Model OHV350-II. The enclosing frame and canvas cover are shown in Figure 5.

For filling the tanks, a submersible pump (GSW Model 3SE-101) and a 15 m, 6.3 cm fire hose were purchased. To reduce the time required to dump the ballast, a 10 cm valve and short standpipe were added. The original 5 cm valves were retained to facilitate the draining of any remaining water in the tanks.

2.2.4.5 ELECTRICAL

As originally conceived, the ACIB would have no onboard AC generating capability. For operational use, all electrical services including lighting, instruments and controls would be powered by DC from the engine alternators and batteries. When docked or beached, AC ground power would be used for engine heaters and battery chargers. With the planned addition of deck lighting, control room electric heaters, ballast tank heaters and test instrumentation, an onboard AC generator would be required. As a temporary measure for the duration of the trials, a rental 12.5 kW single phase 110/220 V AC generator was installed.

2.2.4.5 ELECTRICAL (Cont'd)

As the repair and modification program proceeded, additional requirements for onboard power arose. Operation of the hydraulic system in varying temperature and humidity conditions caused condensation problems necessitating the installation of hydraulic tank heaters. Also, further consideration of lighting for the under-deck video camera pointed up the need for additional illumination over that provided by the 12V halogen headlights attached to the camera mount. For this purpose, four underwater pool lights were installed at the extremities of the buoyancy tanks. Additionally, power outlets for trouble lights, power tools and the submersible ballast pump were installed on the engine enclosures and other locations. As anticipated, a full scale turn on of AC-powered services overloaded the generator. Further, when operating on ground power, all of the new services were across one of the three phases badly unbalancing this load.

In consideration of keeping the onboard power source compatible with the ground power source, it was decided that a 3 phase generator would be installed and the circuits re-wired to provide a balanced load. It was determined that an 18 kW generator would be adequate; however, the only 3 phase rental generator available locally was rated at 30 kW. This unit was obtained and installed prior to the Small Vessel Tests.

2.2.4.6 CONTROL ROOM

Previous experience had shown that the Control Room was unacceptably noisy and cold. The noise level was such that communication with the ship was virtually impossible. Noise suppression microphones were procured in an attempt to resolve the problem; however, these were found to be ineffective since the noise spectra spanned the audio range. It was therefore decided that the Control Room would be insulated, sound-proofed and heated. This was done by removing the ice-shedding fabric cover and sheeting in the metal frame with an outer and inner skin of plywood with a core of rigid insulation. Windows of Lexite in the same locations as those in the flexible cover were also installed.

2.2.4.6 CONTROL ROOM (Cont'd)

For sound suppression, 2.5 cm perforated foam rubber was installed over the interior walls and ceiling. After the Control Room was framed in, the flexible ice-shedding cover was re-installed.

2.2.4.7 FANS

To minimize the ice build-up on the inlet screens and inlet guide vanes, deflectors were installed on each of the three fans in such a manner as to draw air from the interior area of the ACIB. The deflectors consisted of a welded angle iron frame covered with canvas.

Additionally, extendable rubber boots were fitted to the inlet guide vane actuators and the welds holding the inlet screen in place were replaced by studs, washers and lock-nuts for ease of removal and replacement.

2.2.4.8 HYDRAULICS

The initial work on the hydraulic package consisted of the following:

- Enclosing the hydraulic package with a weather protective cover comprised of a removable metal top and flexible side covers with openings for access to hand controls and a window for viewing the gauges.
- Installing brackets to support the reverse flow filters and servicing the gauges.
- Installing a steel balance line in place of the temporary rubber line and new gate valves of line size.
- Relocating the fluid level sensors at a lower point in the tanks.
- Relocating the between-winch lines to deck level and installing protective covers.

2.2.4.8 HYDRAULICS (Cont'd)

- o Modifying the winch controls to provide a "dead man" return to the "neutral" position when released.

During functional checks of the hydraulic system, the condensation problem mentioned above was encountered necessitating the installation of hydraulic tank heaters. Despite the addition of heaters and the purging of the hydraulic tanks, problems persisted. The Moog controllers would not centre in the "off" condition. This resulted in uncommanded payout of the winches. In-situ zeroing of the controllers could not be achieved so they were removed for bench checking at Vulcan. One was found to be unserviceable and replaced; however, even on a hydraulic test bench the serviceable units were extremely difficult to adjust. A subsequent check with the supplier revealed that production of the particular Moog controller model installed on the ACIB had been discontinued because of the sensitivity problem and replaced by a less sensitive model (No. 63-500). Accordingly, the replacement units were ordered and installed.

Even though the replacement controllers were more reliable than the originals, nevertheless, it was possible for them to malfunction during cold weather operation and indeed this happened during functional checks of the system. If a controller failed to return to the "off" condition when control voltages were removed, hydraulic pressure could be provided to winch brakes causing them to come off allowing cable to pay out under load. Such an occurrence could be extremely dangerous during operations, therefore, a means of ensuring against uncommanded release of the brakes was sought. The solution adopted was to install a solenoid valve in the brake hydraulic lines to isolate them when the system was "off" electrically. Figure 6 refers.

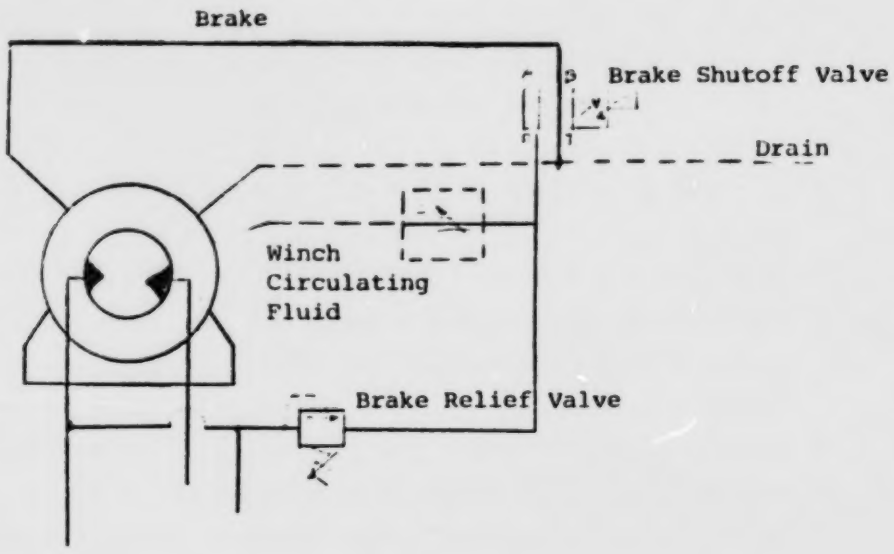


FIGURE 6: Winch Brake Modification

FIGURE 7: Inspection Hatch

2.2.4.9 WINCHES

Cables: During prior operations with the ACIB, extensive damage had been done to the transit and notch winch cables. This was attributed in part to the stiffness of the cables which gave rise to fouling on the cable drums and in part to the need for the transit cables to run at angles of 90° and greater to their normal line of travel. It had been recommended that the cables be replaced with a more flexible type and also that the transit cable fairleads be replaced with Port Colborne fairleads.

In establishing work priorities, it was recognized that replacement of the transit and notch cables was essential from safety considerations and that the replacement cables should be more flexible. Accordingly, the following cables were procured and installed:

- **For the notch winches:** two lengths of 3.8 cm (1 1/2") diameter, 6 x 41 IWRC Langs Lay, 44.8 m (147') long cable with a 0.6 m x 1.2 m (2' x 4') eye in one end; and

- **For the transit winches:** two lengths of 1.9 cm (3/4") diameter, 6 x 36 IWRC Langs Lay, 155 m (508') long cable with a 0.6 m x 1.2 m (2' x 4') eye in one end.

Fairleads: Regarding the Port Colborne fairleads, a cost estimate for fabricating two of these items was obtained. Considering the financial constraints of the program and the $13,800 estimate of the cost of these items, it was decided to defer their procurement and installation. To aleviate the problem somewhat, it was decided that the existing fairlead roller assemblies would be rotated 180° to prevent the transit cables from scrubbing on the sharp edges of the fairlead frames when the cable was run out at an angle.

2.2.4.10 ENGINES

The repair and modification work performed on the engines and their associated components was as follows:

- The fuel vent valves were modified to rectify a problem with automatic shut-off of fuel flow when the tanks were full.
- The screwdriver operated latches on the engine compartment inspection doors were replaced with hand-operated latches.
- Seals were installed around exhaust and air intake stacks to prevent ingress of water.
- The tachometers were calibrated.
- New battery boxes were fabricated and installed to provide adequate physical and environmental protection and new batteries provided.

2.2.4.11 INSTRUMENTS

The following work was performed on the instruments:

- Fan guide vane "fully open" indicator lights were installed in the Control Room instrument panels.
- The DC charging meter gauge circuits were rewired to achieve proper functioning.
- The existing, transducer-operated cushion pressure gauge in the Control Room was replaced with a self-contained pressure gauge.
- The remote control console was functionally checked and calibrated. All controls and gauges functioned properly with the exception of the cushion pressure gauge which remained inoperative during the trials.

2.2.4.12 MISCELLANEOUS STRUCTURAL WORK

Additional work as follows was performed:

- A ladder guide-way spanning the fuel line and a ladder support were installed.
- A missing wheel on the ladder was replaced.
- Weather protective flaps were installed over the manual activating levers on the engine Halon fire extinguishers.
- Fire extinguisher retention brackets were re-worked to ensure quick release.
- Handrail stanchions were repaired as necessary and all were modified to be removable.
- Expanded metal walkways were installed in all work areas of the decks in lieu of anti-skid painting. The latter could not be accomplished during the prevailing cold weather.
- The continuous handrail cable was provided with removable sections for ease of access.
- All under-deck bolts not having adequate thread engagement were replaced with bolts of the proper length.
- An inspection hatch as shown in Figure 7 was installed in the area under the Control Room access stairs.
- Work shelters were provided at each of the three engines. The shelters were comprised of a welded metal frame, sheet metal roof and a canvas cover.

2.2.4.13 SAFETY EQUIPMENT

The life rings and inflatable life rafts which had been stored aboard the ALEXANDER HENRY were re-installed.

Life preservers provided by the ALEXANDER HENRY were stowed in the enclosure under the Control Room.

Four exposure suits were procured for the German & Milne crew. The Coast Guard crew members had their own exposure suits.

Four hard hats with noise suppression ear protectors were procured. Two of these were fitted with earphones and microphones. The latter were for use by the ACIB deck officer and the ship's deck officer respectively.

The fire extinguishers were inspected and certified by a local safety supply company. The engine Halon fire extinguishers were recharged.

2.3 TEST INSTRUMENTATION

2.3.1 Requirement

The following performance parameters were to be measured during the test program:

ACIB:

- Engine RPM
- Cushion pressure
- Hover height
- Trim angles
- Fuel consumption
- Weight
- Video documentation of icebreaking dynamics above and below deck

2.3.1 **Requirement** (Cont'd)

Ship:

- o Engine/Shaft RPM
- o Speed
- o Fuel consumption

Ice Conditions:

- o Thickness
- o Path width
- o Piece size
- o Water temperatures

Environmental Conditions:

- o Air temperature
- o Wind velocity
- o Barometric pressure

2.3.2 **ACIB Instrumentation**

2.3.2.1 ENGINE RPM

The existing tachometer gauges located in the ACIB Control Room were used to obtain engine RPM data. These were calibrated against a hand-held electronic tachometer which was used to measure engine drive shaft RPM directly.

2.3.2.2 CUSHION PRESSURE

The available U-tube water manometer was installed in the Control Room to obtain cushion pressure data. This unit was used in preference to the instrument panel cushion pressure gauge because of its greater precision and damping.

2.3.2.3 HOVER HEIGHT

This was obtained by employing a surveyor's tape suspended from a plank mounted on the starboard side of the ACIB in line with the transverse axis.

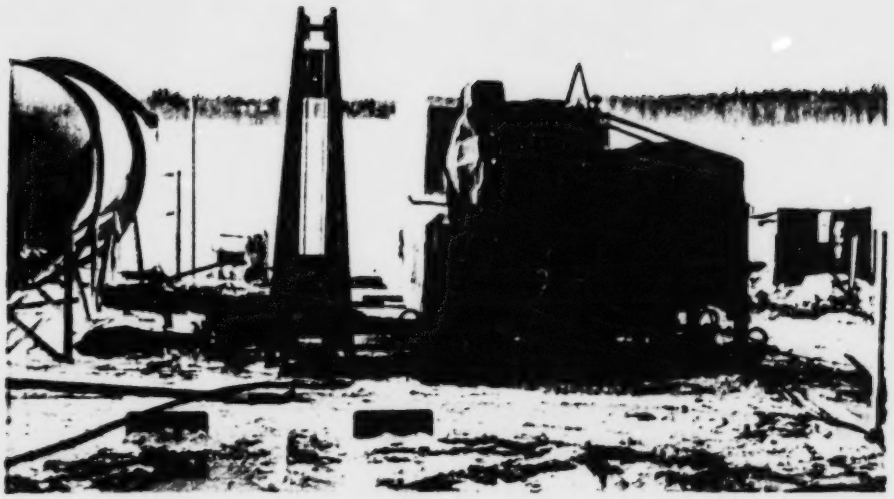


FIGURE 8: Underdeck Video Camera Mount

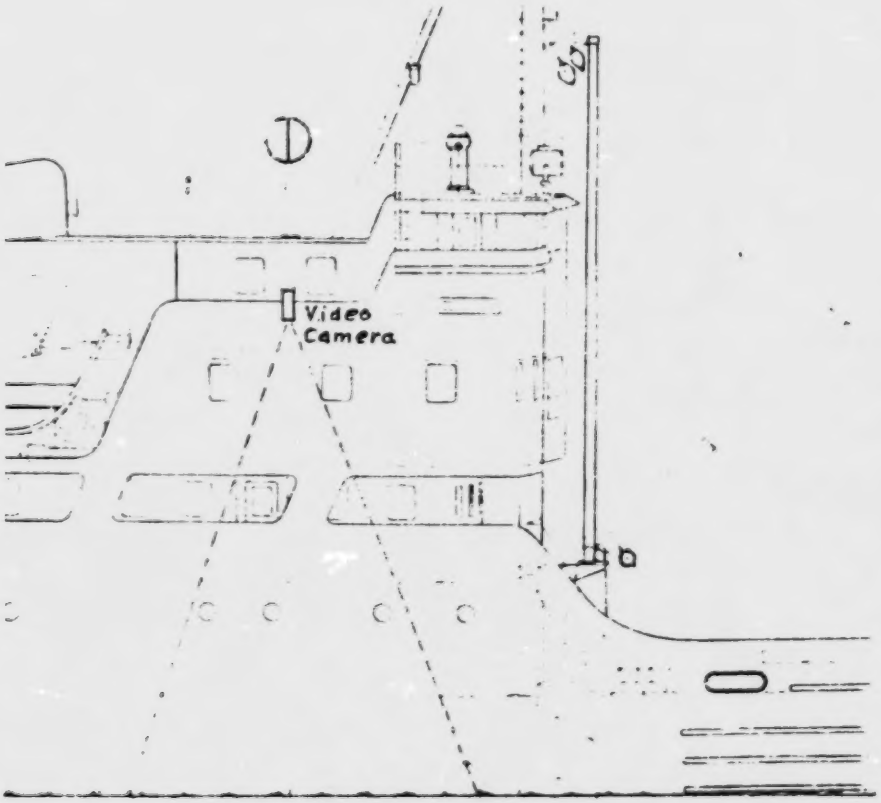


FIGURE 9: Video Camera Installation for Speed Measurements

2.3.2 **ACIB Instrumentation** (Cont'd)

2.3.2.4 TRIM ANGLES

These were obtained with an inclinometer calibrated in percent of 45°. Fore and aft and transverse measurements were taken at a spot marked on the centre buoyancy tank.

2.3.2.5 FUEL CONSUMPTION

This was determined by recording the time between refuellings during a test run and the amounts of fuel added.

2.3.2.6 WEIGHT

The weight and centre of gravity of the ACIB in its various test configurations were determined by recording the weight and location of all added items including equipment, ballast and fuel and calculating the incremental change to the known basic weight and centre of gravity.

2.3.2.7 VIDEO DOCUMENTATION

An underdeck video camera was installed to obtain information on icebreaking action and segment condition. The installation consisted of a video camera mounted in a cylindrical waterproof container with a transparent panel in one end. Interior heaters were provided to reduce the effects of condensation and icing of the window. The camera container was installed in a mounting bracket which also housed two Halogen automobile headlights. This assembly was attached to a 5 cm pipe fitted with a flexible joint to minimize damage to the camera from ice strikes. The unit was suspended through a sealed hatch in the deck. It was raised and lowered by means of a pulley and winch device shown in Figure 8. The camera video output was fed to a Panasonic VCR located in the ACIB Control Room and in turn to a 23 cm TV monitor also located in the Control Room. Rotation of the video camera was achieved by manually turning the support tube. Additional under-deck lighting was provided by the underwater lights described in paragraph 2.2.4.5.

2.3.2.7 VIDEO DOCUMENTATION (Cont'd)

Above-deck video documentation was obtained with a rented colour video camera and portable VCR.

2.3.3 Ship Instrumentation

2.3.3.1 ENGINE/SHAFT RPM

The rotational speeds of the ALEXANDER HENRY's engines and propeller shafts were measured with the instrumentation described in detail in Apppendix A. It was comprised of a HP3497A Data Acquisition System and a HP85F Computer. The data signal was picked off from the ship's tachometer circuits which operated the RPM meters in the Engine Room. The data was displayed on a CRT as a progressive plot which was cleared and printed out on a strip chart every 15 minutes.

This instrumentation was not available until 21 February 1983. For tests prior to that date, shaft RPM was read from the tachometer gauges in the ALEXANDER HENRY's Engine Room and relayed to the Trials Manager on the Bridge. The ship's tachometers were checked with an electronic tachometer taking measurements directly from the shaft and found to be accurate in the speed range of interest - 100 to 230 RPM.

For test operations with the THUNDER CAPE, a similar procedure was employed. The shaft RPM was read from the ship's tachometer gauge located in its Bridge. This gauge was calibrated against direct readings taken from the shaft with the electronic tachometer.

2.3.3.2 SPEED

Ship's speed was determined by means of a video camera mounted in such a manner as to view the passage of ice along the side of the ship from a location as high above the waterline as practical. The video output of the camera was fed to a TV monitor which had a time/date presentation superimposed on its screen from a time/date generator. Speed was determined by measuring the time of passage of ice between calibration marks on the TV monitor screen. These marks were obtained by viewing

2.3.3.2 SPEED (Cont'd)

markers at the ice level of a known distance apart. The location of the camera on the ALEXANDER HENRY is shown in Figure 9. The video signal on the TV monitor was recorded on a VCR for post-test analysis. Periodic checks of the speeds obtained with the video camera were made against speed determinations made with the ship's navigation equipment.

2.3.3.3 FUEL CONSUMPTION

The ALEXANDER HENR. . fuel consumption was determined by recording the fuel flow meter readings at the beginning and end of a test run and periodically during the run as required for the tests being performed.

2.3.4 **Ice Conditions**

2.3.4.1 ICE THICKNESS

During trials with the THUNDER CAPE, ice thickness measurements were made by having a person lean over the aft working deck bulwark and measure the ice thickness directly with a tape measure. For ice thickness measurements during trials with the ALEXANDER HENRY, a pike pole fitted with a rod marked in 15 cm intervals was employed.

2.3.4.2 PATH WIDTH

This was determined by estimating the distance beyond the beam of the ACIB that ice was being broken.

2.3.4.3 PIECE SIZE

This determination was made by scaling characteristic pieces as seen in the velocity measuring video camera coverage of the ice passing the side of the ship.

2.3.4 **Ice Conditions** (Cont'd)

2.3.4.4 WATER TEMPERATURES

These measurements were made by the ALEXANDER HENRY crew as a matter of routine and on request for trials data. The equipment employed was a small diameter plastic bucket with a thermometer mounted centrally in it. The bucket and thermometer were dropped overboard on a lanyard and immersed in the water a few feet below the ice level.

2.3.5 **Environmental Data**

Air temperature, wind velocity and barometric pressure data were obtained from the ship's instrumentation for the tests with the ALEXANDER HENRY. For other tests, these data were obtained from the THUNDER BAY weather office.

2.4 **INITIAL TESTS - UNNOTCHED**

2.4.1 **Functional Tests**

Functional tests of ACIB engine and hydraulic systems proceeded in parallel with the final stages of the repair and modification program. During these tests, the problems with the hydraulic system control valves and winch brakes described above were encountered and resolved. Similarly, the overloading problem with the 110/220 V single phase generator was identified, a replacement generator rented and installed and necessary wiring changes made. Resolution of these problems required urgent action in order that the start of the test program would not be delayed.

Work on these problems continued until the commencement of the small vessel tests on 27 January 1983. In the interim, the over-land and over-water (ice) tests were performed.

2.4.2 Tests Over Land

On 17 January 1983, the over-land tests commenced with the initial inflation of the skirts being carried out. During these tests, it was determined that the skirts in the bow section were frozen in and that additional effort would be required to free them. In addition to clearing out as much of the ice as possible by hand from the skirts, more trim ballast than provided by the trim tanks would be needed. Therefore, the trim tanks were removed and replaced by four 4045 kg (8900 pound) concrete ballast blocks. On 19 January 1983, the craft was again brought up on hover and this time the frozen skirts came free. The craft was then taken off hover and an under-deck inspection of the skirt segment was made to check that there was no damage to them as a result of being freed from the ice. None was observed and a subsequent hover test was performed to check for proper skirt inflation and to complete the overland tests.

With the exception of the known problems with the hydraulics, all systems functioned satisfactorily. The skirt segments hung properly and the notch segments were well formed and uniform in shape. The soundproofing and insulation of the Control Room achieved a marked reduction in the noise level and greatly improved crew comfort. The previously identified problem with the location of the control panels remained and would have to be resolved before the craft could be considered fully operational, however, they were functional and considered adequate for the purposes of the test program. A number of minor deck leaks were observed but these did not result in a noticeable loss of cushion pressure. The newly installed fan deflectors achieved their intended purpose, however the requirement for additional cross members to prevent excessive billowing of the canvas covers was identified and remedial action taken. Communications from the Control Room to the on-deck crew stations were markedly improved as a result of the soundproofing of the Control Room. The addition of the deck hatch proved to be an invaluable asset.

2.4.2 Tests Over Land (Cont'd)

During the hover tests, the onset of heave occurred when the speed of all three engines was brought up to 1600 RPM. At 1500 RPM, a cushion pressure of 66 cm H_2O and a hard structure clearance of 1.4 m was achieved. The fore to aft trim angle was 3° nose down (2° relative to the beaching pad). These and other hover data obtained during the trials are listed in Section 3.2.8.

2.4.3 Launch

For the launch operation, it was decided that additional trim ballast would be required to level the craft on hover. The tight notch seal was providing more lift in the aft end than anticipated. Accordingly, two more ballast blocks were added bringing the trim ballast weight up to 24,650 kg (54,350 lbs). The all-up weight of the ACIB was 208 tonnes.

In preparation for launching, the services of a TD25 bulldozer were obtained. The TD25 was positioned approximately 60 m astern of the craft to act as an anchor point for the notch winch cables and to provide additional winch payout capability during the descent of the craft down the sloped ramp. Once onto the ice surface, the ACIB was winched around 180° into position for notching with the ship by means of the transit winches and transit cables with the latter being connected to bollards progressively further along the dock.

The launch operation was carried out on 20 January 1983. The launch proceeded smoothly and no damage was incurred except to the port transit cable. With the deck level of the ACIB on hover being much higher than the dock level, the cable scrubbed over the edge of the ACIB deck breaking numerous strands. This incident graphically demonstrated the need for Port Colborne fairleads. Approximately 30 m of the new cable had to be removed as a result of this damage.

2.4.4 Port Colborne Fairleads

A hurried search for a source of Port Colborne fairleads revealed that two used ones from a scrapped freighter could be obtained from Western Engineering of Thunder Bay. These were procured through Vulcan Machinery who overhauled them, mounted them in a frame as shown in Figure 10 and installed them on the craft. All of this work was accomplished in the three day period from 24 to 26 January 1983.

2.4.5 Checkout Over Water

For the ACIB checkout over water, the craft was ballasted to its maximum all up weight. The solid trim ballast used for the launching operation was removed and replaced by the water ballast and all 22 ballast blocks loaded onto the craft in its central deck area. With the water ballast tanks filled, the total weight of the ACIB was 282.4 tonnes.

The objective of this phase of the program was to obtain experience in handling the craft and to obtain hover performance data operating alone and notched to the ALEXANDER HENRY.

The hover tests alone were performed on 21 January 1983. During these tests, cushion pressure, hover height and trim angles were measured at engine speeds of 1200, 1500, 1800 and 2100 RPM, operating on one, two and three engines. The results of the tests are tabulated in Section 3.2.8.

On the same day, an attempt was made to notch the ACIB with the ALEXANDER HENRY to obtain hover test data in the notched configuration. The data of particular interest was the hover height and cushion pressure capability of the craft with one and two engines inoperative.

Several attempts were made to notch with the ALEXANDER HENRY, however, the build-up of ice between the ACIB and the ship, and the limited distance between the ship and the dock, prevented the achievement of a notching. After two hours of operation, the notching attempt was

FIGURE 10: Port Colborne Fairlead

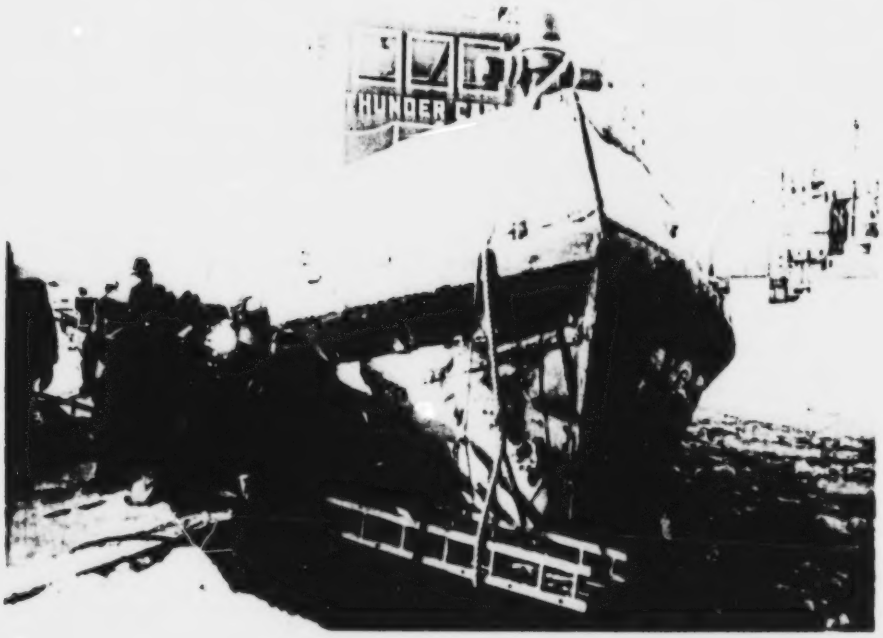


FIGURE 11: Work on the THUNDER CAPE's Bow

2.4.5 **Checkout Over Water** (Cont'd)

terminated since the centre hydraulic package was overheating as a result of a Moog valve malfunction. The ACIB was then winched back along the dock to its berthing position and connected to ground electric power. As the ACIB would now remain in the water for extended periods of time, a crew watch system was established to bring the ACIB up on partial hover every 8 hours to break the skirts free of ice.

The test program had called for static notching tests and a short shakedown icebreaking operation with the ALEXANDER HENRY prior to proceeding with the small vessel tests with the THUNDER CAPE. As these tests were scheduled for the period 24 to 27 January and could not be slipped because of prior commitments for the THUNDER CAPE and, further, for safety considerations, icebreaking operations could not be undertaken until the solenoid valves were installed in the ACIB winch brake lines, it was decided to defer the notching and shakedown tests with the ALEXANDER HENRY and proceed with the preparations for the small vessel tests.

2.5 TESTS WITH TUG THUNDER CAPE

2.5.1 Arrangements

For the small vessel trials, arrangements were made with Western Engineering Ltd. for the services of the tug THUNDER CAPE during the week of 24 to 28 January 1983. The charge for its services was $500 per hour for each hour of operation. For notching with the ACIB, it would be necessary to remove the THUNDER CAPE's bumpers and anchor and any of their support brackets that could snag the ACIB's notch skirts, and also to install fairing plates under the tug's strakes to prevent the ACIB notch beams from hanging up on the strakes when the craft came up on hover. The arrangement with Western Engineering called for both the preparation of the THUNDER CAPE's bow as described above and its return to its original configuration. This work was to be performed by Vulcan under the terms of the contract for repair and modifications of the ACIB and support for the trials program. The schedule of activities called for the preparatory work to be done on 24 and 25 January, the icebreaking trials on 26 January and the restoration work on 27 and 28 January.

2.5.2 Preparations

At 0600 on 24 January 1983, the ALEXANDER HENRY departed the Coast Guard dock to break a path to the Shipyard dock for the THUNDER CAPE. At 0915, the THUNDER CAPE arrived at the Coast Guard dock and the preparatory work on its bow commenced. Figure 11 shows this work in progress.

At the same time, the final preparatory work on the ACIB was in progress. By 1100 on 26 January 1983, the following work had been accomplished:

On the THUNDER CAPE:

- The preparatory work on the bow had been completed.
- The test instrumentation was installed.

On the ACIB:

- Two new Moog controllers were installed in the hydraulic package.
- The solenoid valves were installed in the winch brake lines.
- One of the two Port Colborne fairleads was installed.
- The underdeck camera and TV monitor were installed.
- The single phase generator was removed and replaced by a three phase generator.
- All but 4 of the ballast blocks had been removed to achieve the light ballast condition required for the small vessel tests.

During the same time period, the need for a back-up heater for the water ballast tanks became evident. The heater which had been running for several days to keep the water ballast from freezing malfunctioned and had to be replaced by two smaller rental units until the main unit could be repaired. Subsequently, a second heater was procured.

Since the preparatory work on the THUNDER CAPE and the ACIB had not been completed in time for a full day's testing on 26 January, the tests were re-scheduled for 27 January.

2.5.3 Icebreaking Tests

2.5.3.1 OBJECTIVE

The objective of these tests was to demonstrate the icebreaking capability of the ACIB operating with a small non-icebreaking vessel and to measure the width of the broken path. Additionally, the practical speed of icebreaking with such a vessel was to be determined as well as the ACIB performance parameters of cushion pressure, hover height and trim angles.

2.5.3.2 NOTCHING OPERATION

For the notching operation, the ALEXANDER HENRY broke open an area of ice approximately 200 m in diameter at the entrance to the Coast Guard slip. This was done to provide an adequate area for manoeuvring the THUNDER CAPE and ACIB into proper alignment for notching. At 0920 on 27 January, the THUNDER CAPE towed the ACIB on hover to the notching area. The notching operation commenced at 0940 and was completed in 35 minutes without incident. There had been some concern that the weight of the water trim ballast would not be adequate to keep the ACIB level when notched to the THUNDER CAPE since, in the unnotched state, there was a nose down attitude of 3 degrees. Therefore, the THUNDER CAPE was brought into the notch as far as possible to reduce the lift on the aft end of the ACIB. In this condition, there was a nose up attitude of 1.5 degrees with all of the water ballast retained. Because of the need to keep the notch as low as possible on the THUNDER CAPE due to the potential notch boom/ship's strake interference problem, the water ballast was retained for the operational trials. In this condition, an excellent notch seal was achieved and very little spray resulted.

2.5.3.3 INSTRUMENTATION CHECK

Following the notching operation, the underdeck video camera on the ACIB was lowered into position and the connection made between the camera and the video cassette recorder aboard the THUNDER CAPE. As originally planned, the underdeck camera video and the speed measuring

2.5.3.3 INSTRUMENTATION CHECKS (Cont'd)

camera video would both be recorded on the VCR on a time-shared basis. However, the signal from the camera on the ACIB could not be recorded on the VCR because of a frequency incompatibility. The underdeck camera sweep generators were not crystal controlled whereas those in the VCR were. As the ACIB generator frequency varied widely, the incompatibility resulted. As the underdeck camera information was not categorized as essential to this phase of the trials, the decision was made to proceed without it. The coverage was, however, monitored on the TV monitor aboard the ACIB but its performance was intermittent due to the frequency variations.

Early in the trials, an additional power source problem developed. Although the THUNDER CAPE's AC generator frequency was within tolerance for the speed video camera/VCR combination, the time/date generator would not hold the time/date settings for more than a few minutes due to power surges. To provide periodic time references on the tape, this information was interjected by voice on the audio channels. The stop watch function of the generator remained operational and this was used for speed determinations.

2.5.3.4 ICEBREAKING TRIALS

Two discrete ice thickness conditions prevailed in the Thunder Bay harbour area at the time of the trials. Inside the breakwater, the ice was 60 to 66 cm thick and outside, it was 30 to 35 cm thick. This thickness prevailed from the breakwater to the Welcome Islands. Beyond the islands, there was open water. In general, the ice surface outside the breakwater was smooth with a few patches of light snow with the exception of the pressure ridges where drifting snow had collected. Inside the breakwater the ice was covered with about 5 cm of partially frozen snow.

2.5.3.4 ICEBREAKING TRIAL (Cont'd)

For the small vessel tests, the initial runs were made parallel to the breakwater on the lakeward side in 30 cm ice to assess performance at increasing speeds and to check turning capability. Following this, tests were made inside the breakwater in the 60 cm ice. Because of the limited distance available, tests at three throttle settings only were made. After completion of the tests inside the breakwater, longer test runs to the Welcome Islands were made at various speeds to gain additional performance data. As a check on the video speed measuring device, timed runs over distances measured by the ship's radar were made.

During the six-hour period of the trials, performance measurements were made over a distance of 27 km with periodic stops for ice thickness measurements, hover tests and equipment checks. The maximum speed attained in the 30 cm ice was 5.4 knots and in the 60 cm ice was 3.0 knots. Detailed performance information is contained in Section 3.3.

Unfortunately, the underdeck camera suffered an ice strike during the run to Welcome Island and its services were lost for the remainder of the day's operation.

2.5.4 **Post-Test Observations and Inspection**

The tests clearly demonstrated the feasibility of breaking ice up to 65 cm with the ACIB/small vessel combination. Of particular note was the small turning radius of the combination which was found to be 25 m.

All of the basic ACIB equipment worked satisfactorily except for some overheating of the hydraulic fluid which was subsequently determined to be caused by a main pump null position adjustment being out of tolerance. Additionally, the performance of the rental 3 phase generator was marginal.

2.5.4 **Post-Test Observations and Inspection** (Cont'd)

The adjustment to the spray skirt attachment linkage wherein this was reduced to a shackle-to-shackle link was very effective in reducing spray, however, by the latter half of the test run the gap between the apron and the deck had iced over blocking the escape of air. This resulted in a mild porpoising of the craft as the build-up of air pressure under the spray apron periodically vented out the bottom of the apron.

From the limited underdeck video camera coverage, it appeared that there was no damage to the skirt segments themselves but possibly some damage to the skirt sole pieces in the bow area of the craft. The value of the underdeck camera was clearly demonstrated as was the need for a crystal controlled camera to provide reliable operation and a separate VCR to enable continuous recording of the coverage to be made.

The post test inspection of the craft's notch area revealed that only minor damage had been incurred. There was a 20 cm tear in the No. 4 notch segment near the notch boom extension and two D-ring connectors between the inboard and mid-section sub apron were missing. Temporary repairs were made to the D-rings, however, repairs to the tear in the notch segment were not made because of time considerations and the fact that the area of the tear would seal against the hull of the ship.

Work on the THUNDER CAPE to remove the fairing plates and replace the anchor and bumpers commenced on 28 January and was completed on 31 January. The tug returned to the shipyard on 1 February through a path broken by the ACIB/ALEXANDER HENRY.

2.6 TESTS WITH CCGS ALEXANDER HENRY

2.6.1 Initial Notching and Functional Tests

Initial notching and functional tests with the ACIB/ALEXANDER HENRY in motion were performed on 28 January 1983. For the notching operation, the ACIB was towed by the THUNDER CAPE to the area of broken ice at the entrance to the CCG slip. The ALEXANDER HENRY manoeuvred into position and the ACIB transit and notch cables were attached. The notching operation proceeded smoothly and was completed in 40 minutes. A tight notch seal was achieved and the notch segments were well formed, as shown in Figure 12. Fuel lines, control lines and communications lines were attached and checked out. All worked satisfactorily. The hard line communications between the ship's Bridge and the ACIB Control Room were excellent. Also, the radio link used prior to and during hook-up worked well attesting to the effectivensss of the soundproofing of the ACIB Control Room. The access ladder could not be attached because of a bent fitting on the ship's end attachment. Additionally, the requirement to extend the length of the ladder ramp on the ACIB deck was noted.

Brief pre-notch and post-notch hover tests were performed. In the unnotched condition with all three engine speeds set at 1600 RPM, a cushion pressure of 71 cm H_2O and a trim angle of 2° nose down were achieved. When notched, with all water ballast retained and engine speeds at 1600 RPM, the cushion pressure was 75 cm H_2O and the trim angle 2° nose up. With the trim ballast dumped, the trim angle was 1° nose up. The hover height achieved under these conditions was 3.35 m. For the light weight performance trials which were to follow the functional tests, 4 ballast blocks had been installed giving an all-up weight of 201 tonnes and a centre of gravity 0.78 m ahead of geometric entre. This data is summarized in Section 3.2.8.

FIGURE 12: Inflated Notch Segments

2.6.1 **Initial Notching and Functional Tests** (Cont'd)

During the subsequent shakedown runs, a distance of 8 km was covered in 2.5 hours. For the most part, the ship's shaft speed was limited to 190 RPM. At this setting, a speed of 2 knots was achieved in 60 cm ice and 5 knots in 30 cm ice. The trials demonstrated the feasibility of icebreaking with the ACIB/ALEXANDER HENRY combination. There was no stacking of ice slabs along the ALEXANDER HENRY's bow and a consequent wedging-in of the ship as had been noted in the Spring 1982 tests.

A short time after the commencement of the shakedown runs, the rental 3 phase generator failed. The remainder of the operation was completed on DC power only.

2.6.2 **Performance Trials**

2.6.2.1 OBJECTIVES

The objectives of the performance trials with the ALEXANDER HENRY was to obtain quantitative data on icebreaking over as wide a range of ice conditions as possible and to familiarize the crew of the ALEXANDER HENRY with the ACIB. In particular, performance data in ice thicknesses of 30 cm, 65 cm and 100 cm were required. The prevailing ice conditions inside and outside the harbour breakwater would satisfy the requirement for tests in 30 cm and 65 cm ice, however, it did not appear likely that 100 cm ice would be encountered because of prevailing moderate winter temperatures.

The specific performance data required was:

- Icebreaking speed vs. ship's shaft RPM;
- Turning circle radii in each ice condition;
- Fuel consumption;
- Width of broken path and size of broken pieces;
- ACIB performance parameters including any change of trim associated with changes in speed.

2.6.2.2 PREPARATIONS

Prior to the commencement of the performance trials with the ALEXANDER HENRY, the deficiencies noted during the functional tests were rectified. This work was done during the weekend of 29/30 January. It entailed the following:

- Obtaining and installing a second rental 3 phase generator to replace the one that had failed during the functional tests.
- Removing 30 m of damage transit winch cable and splicing a new eye on the free end.
- Repairing the underdeck video camera and camera mount.
- Modifying the ladder ramp which spanned the fuel line.

Additionally, the second of the two Port Colborne fairleads was installed and the speed measuring video camera equipment was transferred from the THUNDER CAPE to the ALEXANDER HENRY and calibrated.

Further preparatory work was done on 31 January prior to the departure of the ACIB/ALEXANDER HENRY on the initial performance trial. This entailed the procurement and installation of a second VCR to record the underdeck camera video (as authorized by TDC) and the installation and final check-out of the underdeck camera. Also, the CCG Chief Engineer for the ACIB, Mr. E. Gerow, made arrangements for the transfer from CCG holdings of a 3 phase generator to replace the highly unsatisfactory rental generators.

2.6.2.3 TRIAL RUNS

The first of the icebreaking performance trials was conducted on 31 January 1983. These trials were aimed at obtaining an initial sampling of the required data. The first test run of the day's operation was made inside the breakwater at shaft speeds of 210/215 RPM (Port/Starboard shafts). The ice encountered was 65 cm thick with a covering of 5 cm of old snow and 10 cm of new snow. The maximum speed achieved during the run was 3.0 knots.

Unfortunately, 180° turning radius checks inside the breakwater (without a backing manoeuvre) were not feasible because of the narrow width of the dredged channel.

The tests outside the breakwater in 20 to 40 cm ice were aimed at determining icebreaking speeds versus shaft RPM over as wide a range as possible plus changes in trim angle, turning circle performances and fuel consumption. Runs at shaft speeds of 100/100 RPM achieved speeds of only 1.0 to 1.5 knots indicating that this was not a practical shaft speed for icebreaking. Shaft speeds ranging from 150/150 to 225/230 achieved speeds of 2.5 knots and 5.9 knots respectively. During these runs, there was no measurable change of trim angle. For the turning radius determination, a 360° turn was made with shaft speeds of 220/225 and the rudder hard over. The diameter of circle achieved was 1200 m. This was measured with the ship's radar which showed the broken path clearly.

In the 3.25 hours of test runs a distance of 25 km was covered at an average speed of 4.3 knots. The average fuel consumption for the day's operation was 288 litres (63.6 gals) per hour for the ACIB and 353 litres (77.8 gals) per hour for the ALEXANDER HENRY.

The ACIB remained notched to the ALEXANDER HENRY overnight in readiness for the following day's operations.

2.6.2.3 TRIAL RUNS (Cont'd)

Further performance trials were carried out on 1 February 1983 with the ballast conditions remaining the same as the previous day's. The principal objective of these trials was to obtain further information on fuel consumption. It was apparent that a comparison of fuel consumption per kilometer of ice broken with the ACIB/ALEXANDER HENRY combination with that of the ALEXANDER HENRY working alone would be more meaningful than a comparison of consumption per hour of operation. Further, it was felt that a determination of the optimum speed from a fuel economy point of view would be of value. Accordingly, a number of runs for these purposes were carried out. Additionally, further information on turning circle diameters, ACIB performance parameters, path width, and piece size was obtained.

Icebreaking operations on 1 February commenced at 0700 with the first three hours being dedicated to breaking and widening a track from Keefer Terminal to the Shipyard dock for the return of the THUNDER CAPE and breaking open the Shipyard turning basin for the movement of ships by the THUNDER CAPE on the following day. Performance test runs commenced at 1000 and continued through to 1600.

Fuel consumption runs at incrementally increased shaft speeds ranging from 100/100 to 224/228 RPM were made in ice thicknesses of 35 to 45 cm. The optimum speed for fuel economy was found to be the maximum speed attained which was 5.3 knots at full throttle. However, the range of fuel consumptions was not great except at low speeds - 1.4 knots at 100/100 RPM - wherein the consumption was double that at high speeds. The detailed results are contained in Section 3.2.6.

Turning circle checks were made in 35 cm ice with one engine stopped, the rudder hard over and the other engine at 200 RPM. The diameter of the turning circle was 400 m and the speed 1.7 knots.

2.6.2.3 TRIAL RUNS (Cont'd)

A brief test run in the open water beyond the Welcome Islands was also made. During this run a 360° turn was made for comparison purposes with both engines at full speed. The diameter of the circle was estimated to be 400 m, the same as that over ice on one engine. The open water speed achieved in a straight run at maximum shaft RPM was 8 knots.

The path width in 35 to 45 cm ice averaged 32 m (3 m beyond the beam extremities of the ACIB on each side). During these test runs, some increase in path width at high speeds was noted. A decrease in piece size with increasing speed was also observed. The size of the larger pieces decreased from 2.5 m to 2.0 m (major dimension) as the speed increased from 2 to 5 knots. At low speeds, the ice was breaking about 4 m ahead of the craft whereas at high speeds, the initial break occurred inside the bow skirts. The breaking ahead of the craft is clearly visible in the airborne photographs taken during this test run. (Figure 13).

During one of the low speed runs (2 knots at shaft speeds of 150/150 RPM), the craft was brought to a halt by a snow-covered ridge of ice 76 cm thick. The ridge was approximately 65 m in width. It was subsequently crossed by backing and approaching at an increased speed.

2.6.3 Inspection

The underdeck camera had suffered an ice strike during the early stages of the 1 February trials and was rendered inoperative for the rest of the day's operations. During the last run of the day heading towards the Keefer Terminal, the crew of the ALEXANDER HENRY reported a black object about 75 cm wide by 240 cm long flying aft from under the ACIB. As it was suspected that the object was a skirt sole, an underdeck inspection with the video camera was planned. After docking the camera was removed, repaired and re-installed. On the following morning, the ACIB was placed on hover and the skirts inspected. The inspections revealed that several sole pieces were torn and a number missing completely. It appeared that there might be some damage to the skirts themselves but this could not be determined without a physical inspection. The decision was therefore made to de-notch the ACIB from the ship and beach it for inspection.

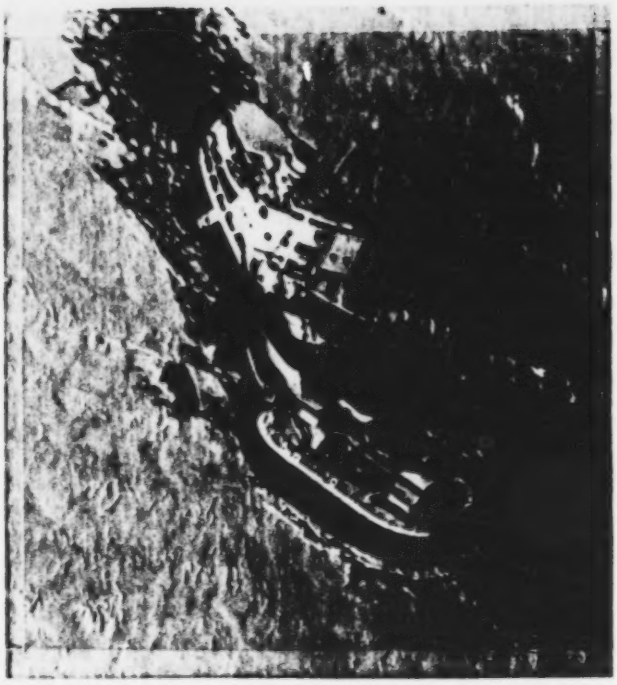


FIGURE 13: Airborne View of ACIB/ALEXANDER HENRY

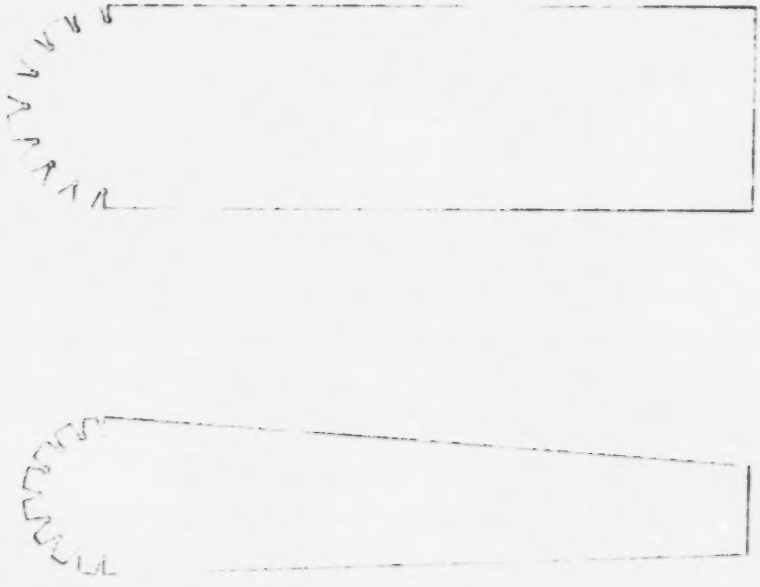


FIGURE 14: Closed Sole Modification

2.6.3 **Inspection** (Cont'd)

The inspection revealed that all of the skirt sole pieces in the forward half of the craft were either torn or missing. Of these, 17 were totally missing or held by only 25 to 50 cm of bonding at their inboard end. There was, however, no damage to the skirt segments themselves.

The notch section had also sustained damage. The No. 6 notch boom upper attachment bracket had been broken when the boom hung up on a dock bumper during the replacement of the water ballast tanks with solid ballast in preparation for beaching. Inspection of the notch area revealed that there was damage (tears) to the No. 4 and 5 notch segments inboard of the rub aprons and at the ends of the notch booms. Rub apron D-rings were also damaged as noted following the tests with the THUNDER CAPE.

The results of the inspection and the estimates of costs and time to make repairs were reported to TDC and German & Milne project managers.

2.6.4 **Fuel Consumption - ALEXANDER HENRY Alone**

During the time on 2 February while the ACIB was being beached and inspected, the ALEXANDER HENRY carried out icebreaking operations alone. The ship was required to keep the Shipyard turning basin open for the scheduled movements of ships into and out of the drydock. This opportunity was taken to obtain fuel consumption data on the ALEXANDER HENRY operating alone. Following the icebreaking activities in the turning basin, a run was made in undisturbed ice of 35 cm thickness. During a 1.5 hour backing and ramming operation, the ship had broken a path 1.1 km long. The fuel consumption for this run was 400 l per kilometer (162 gals. per nautical mile).

2.7 REPAIRS AND MODIFICATIONS

The ALEXANDER HENRY was scheduled for self re-fit during the period 7 to 18 February 1983 and this activity could not be deferred because of commitments to clear ice for the movement of ships in the harbour area on 20 February. It was, therefore, decided that no attempt would be made to make temporary repairs to allow the trials to continue for the few days remaining prior to the lay up of the ALEXANDER HENRY. Full scale repairs and modifications commenced immediately and continued through the re-fit period.

The flapped soles intended to protect the forward section skirts from snagging during backing manoeuvres were effective in that mode of operation but during forward motion the soles themselves were subject to snagging. Some consideration was given to operating without sole pieces in the forward section skirts, however, normal icebreaking operations, particularly when clearing the harbour and the slips, would involve considerable backing with the consequent danger of skirts snagging on broken ice and a serious blow-out resulting. It was, therefore, decided that the sole pieces would be retained and that they would be redesigned to function in both directions. The design which evolved was a closed sole as shown in Figure 14. Drainage holes were added in the sole to free the segment of trapped water when the craft came up on hover.

The repair and modification program started on 3 February with the removal of the spray apron and a number of skirt segments. Eventually, all skirt segments were removed as the decision had been made to modify the segments in the aft section as well as those in the forward section. This work was done jointly by Vulcan Machinery and Rematech with the former removing and re-installing the skirt segments and the latter doing the bonding and related work on the skirts and sole pieces. Repair of the damage to the notch section proceeded in a similar manner with the work being done in situ.

2.7 REPAIRS AND MODIFICATIONS (Cont'd)

Work on the CCG-supplied generator proceeded in parallel with the repair and modification of the ACIB. Additionally, the underdeck video camera package was returned to German & Milne, Montreal, for re-work. The camera was replaced with a crystal controlled model and additional strip heaters were installed to combat the icing of the viewing port. Work on the instrumentation for recording the ship's engine and shaft speeds was also underways after some delays in delivery of the components.

Midway through the repair and modification program, it became apparent that the target date for completion of 20 February could not be met, therefore, a one-week extension was agreed upon. The harbour icebreaking operation scheduled for that date was performed by the ALEXANDER HENRY alone.

By 22 February, all of the skirt segments had been repaired, modified and re-installed and work on re-connecting the spray apron was in progress. This work was completed on 23 February and the craft placed on hover to break it free of ice. Full hover tests were planned for 24 February with Dr. Michael Hinchey, of Memorial University, and Mr. Terry Graham, of University of Toronto Institute for Aerospace Studies (UTIAS), in attendance to make hover height measurements in support of a hovercraft hysterisis study in which they were engaged. These tests were to be performed with three, two and one engine operating and hover height measurements versus cushion pressure made as the engine speeds were first increased in small increments and then decreased in like increments. During the initial run on three engines at decreasing speeds, the centrifugal clutch on the Port engine failed as the engines were being operated at 1800 RPM.

Subsequent inspection revealed that the clutch sealed ball bearing assembly had seized fracturing the clutch drum shaft and causing a severe out of balance vibration that also damaged the universal joint in the fan drive shaft.

It was determined that a replacement clutch could be obtained from BLM - Automatic Clutch Ltd. in Scarborough, Ontario; however, the unit could not be delivered until 28 February since it had to be custom balanced for the ACIB high speed application. (Specifications for Model No. FMU140L3 refer).

So that the visitors' trip to Thunder Bay would not be wasted, the hover tests were continued on 25 February on two and one engine respectively. The data obtained is given in Section 3.2.8.

While awaiting the delivery of the new clutch assembly, the centre and starboard clutches and universal joints were removed for inspection and servicing. These units were found to be in good shape, however, the clutch drums showed evidence of some overheating in that the paint on the exterior was scorched. It was known from the clutch literature that clutch engagement occurred between 700 and 900 RPM and this speed regime had been avoided by not operating the engines for any appreciable length of time at speeds from 600 to 1200 RPM. As an added margin of safety, speeds between 600 and 1400 RPM were avoided in future operations.

To confirm that the out of balance condition had not damaged the engine drive shaft or the fan shaft, dial run-out tests were performed on these units. Fortunately, none had occurred. These checks were also done on the centre and starboard engines and fans.

The additional work that was underway during this time period was as follows:

- The engine and shaft speed instrumentation was installed in the ALEXANDER HENRY and calibrated at shaft/engine speeds of 100, 150 and 200 RPM.

- The re-worked underdeck video camera package was installed in the underdeck mount which now had an improved flexible joint in its shaft to minimize the damage caused by ice strikes.

2.7 REPAIRS AND MODIFICATIONS (Cont'd)

- The hydraulic fluid overheating problem was investigated and resolved by the removal, bench testing and servicing of the charge pump and main pump. It was discovered that the main pump null position was out of adjustment resulting in pumping action even when the Moog controller was in the neutral position.

- The 864 kg (1900 lb) hand operated boat winches used to spread the notch booms apart for notching operations were replaced by 1590 kg (3500 lb) electric winches because it had been found that not enough force could be exerted with the smaller winches to perform this operation.

- The RACOR fuel filter heaters were connected to accommodate the increased viscosity and wax content of the fuel being supplied by the ALEXANDER HENRY. This type of fuel was not recommended for use in the ACIB Detroit Diesels.

By 2 March, the clutches and universal joints had been re-installed and functionally checked. On 3 March, the ACIB was placed on hover and launched. Considerable difficulty with the launching operation was encountered because of the depth of snow that was piled in the lee of the dock. However, the operation was successfully completed but it pointed up the need for increased power in the transit winches which were torque limited in conformance with the cable size. To obtain the increased power that was needed, the transit winch cable size would have to be increased from 1.9 cm (3/4") to 2.5 cm (1") and the winch motor torque adjusted accordingly.

2.7 REPAIRS AND MODIFICATIONS (Cont'd)

Following the launch, the 3 phase generator was loaded aboard the ACIB and the starboard trim ballast blocks removed and replaced by the trim tank. On the following day, the ACIB was winched around 180° and the port trim ballast blocks removed and replaced by the trim tank. In preparation for the heavy weight hover tests and subsequent icebreaking trials at maximum allowable all-up weight, the deck ballast was loaded aboard the craft. During this operation, freeboard versus ballast weight measurements were made. The results are tabulated in Section 3.3.

Concurrently, a 2.35 m (8 ft.) by 6.1 m (20 ft.) trailer with sleeping accommodation for 6 persons was loaded aboard the ALEXANDER HENRY and secured in place on the Main Deck. This unit was provided because it was anticipated that there would not be adequate sleeping accommodation aboard the ALEXANDER HENRY for the ACIB crew and the expected official observers.

2.8 OPERATIONAL TRIALS WITH CCGS ALEXANDER HENRY

2.8.1 Operations Alone

As work on the ACIB was not completed on 4 March, the Master of the ALEXANDER HENRY decided to proceed with icebreaking alone commencing at 2300 on that date and extending through Saturday and Sunday, 5 and 6 March. The Trials Manager accompanied the ship on this operation to obtain more information on fuel consumption and to monitor the engine and shaft RPM instrumentation. During 40 hours of icebreaking, with stops for repairs to the newly installed electronic telegraph system, the ship broke a path 18 km long in ice ranging in thickness from 25 to 60 cm. The path width was approximately 60 m. This was achieved by making three ramming runs for each forward progression. The path extended from the Keefer Terminal to open water southeast of the Welcome Islands. Consumption figures for a representative part of the distance covered are given in Table 4.

2.8.2 Trials Objectives

The objectives of the operational trials were to employ the ACIB/ALEXANDER HENRY combination to open channels and clear ice in the Thunder Bay area, to provide CCG personnel with further experience in operating the ACIB and to obtain additional ACIB performance data.

2.8.3 Hover Tests

In preparation for the operational phase of the test program, the ACIB was ballasted to the maximum permissible weight. This was done for the dual purposes of obtaining heavy weight hover test data and checking icebreaking performance at maximum weight.

On 7 March 1983, hover tests with the ACIB operating alone were performed prior to the notching operation. The weight of the craft with trim ballast aboard was 272.8 tonnes. The notching operation itself was complicated by the heavy accumulation of broken ice between the ACIB and the ALEXANDER HENRY, however, it was completed successfully in a two hour period. Subsequently, hover tests in the notched configuration were performed. The weight of the craft with trim ballast dumped was 263.7 tonnes. During the tests cushion pressure, hover height and trim angle data were obtained with the one, two and three engines operating. These tests demonstrated the potential of operating on two engines only.

2.8.4 Heavy Weight Operations

The initial run of the day was made in ice averaging 50 cm thick on a heading of 090° True commencing at the South Entrance to the harbour. The ACIB engines were operated at 1800 RPM with a cushion pressure of 90 cm H_2O and a hover height (deck level to ice level) of 2.90 m being achieved at low speeds. As the speed was increased, a loss of cushion pressure and hover height occurred as a result of violent expulsion of air through fractures in the ice ahead and to the sides of the ACIB. This was attributed to the excessive overpressure in relation to the ice thickness - nearly 2 to 1. As the craft's speed approached 4 knots, slabs of unbroken ice were extending under the craft a distance sufficient to impact on its structure

2.8.4 **Heavy Weight Operations** (Cont'd)

which was then at a level lower than the ice surface. The hover height under these conditions was 2.45 m. The ACIB crew requested that the speeds be limited to 1.5 to 2.0 knots for the remainder of the test runs because of the potential damage to the skirt segment support rods and a possible blow out of segments. This was agreed to and the remainder of the day's operations were performed at these speeds.

It was evident that operations in heavy ice at overpressure approaching twice the thickness of the ice could be hazardous. It was therefore agreed that the ACIB would be operated in the light weight condition for the remainder of the trials since the cushion pressures achieved would be adequate for the prevailing ice conditions. Accordingly, arrangements were made to have a crane at dockside to commence removal of the deck ballast when the ACIB/ALEXANDER HENRY returned from the day's operation.

The docking occurred at 1630 and the ballast removal work was completed at 1800. All but three blocks were removed reducing the craft's weight to 199.7 tonnes.

Excellent underdeck video coverage of the icebreaking action was obtained during the initial part of the trials, however, at the mid point a block of ice lodged in the craft's structure in front of the forward underdeck light reducing the illumination.

During the day's operation a distance of 22 km was covered in ice ranging in thickness from 50 cm outside the breakwater to 65 cm inside the breakwater. The average speed over the 7-hour period of the trials was 3.14 km/hour or 1.7 knots.

2.8.5 Light Weight Operations

2.8.5.1 OBJECTIVES

The objective of the operational trials that took place on 9, 10 and 11 March 1983 was to break channels which would free large tracts of ice that could be drifted out of the harbour area by an off-shore wind. During these operations, additional performance data was obtained.

2.8.5.2 OPERATIONS ON 9 March 1983

Prior to commencing the icebreaking operations outside the breakwater, a period of 1.5 hours was required to manoeuvre the ACIB/ALEXANDER HENRY away from the dock, complete a 180° turn and reach the South Entrance. This and other similar instances of difficulties in getting away from the dock pointed out the need for a docking facility from which the combined craft could exit without the necessity of backing and turning in a confined space.

During the subsequent runs to and from the Welcome Islands, the effect of wind on the craft's speed was noted. With a following wind component of 4 to 5 knots, a speed of 5.4 knots was achieved at shaft speeds of 190/195 RPM in ice measuring 50 cm thick. On a reverse heading with a head wind component of 4 to 5 knots and the shaft speed remaining at 190/195 RPM, the speed was reduced to 4.2 knots. Increasing the shaft RPM to 210/215 brought the speed up to 5.4 knots.

During the latter stages of these runs the ACIB crew reported that they had observed tears developing in the skirt segment sole pieces and requested that the speed be limited to 4 knots to minimize the chance of further damage. This was done for the remainder of the day's operation.

The ACIB/ALEXANDER HENRY returned to the CCG dock at 1500 having completed an icebreaking run of 26 km in length during an elapsed time of 3.4 hours for an average speed of 4.1 knots.

2.8.5.3 OPERATIONS ON 10/11 MARCH 1983

Icebreaking operations on 10 March were scheduled to commence at 0800, however, Northerly winds of 5 to 10 knots prevented the ACIB/ALEXANDER HENRY combination from moving away from the dock. After several attempts, the ACIB was de-notched from the ALEXANDER HENRY and the ship proceeded on its own to widen a path from the dock to the South entrance. At 1300 the ship had returned and the re-notching operation commenced. This operation was complicated by the amount of trapped ice between the ship and the ACIB and their close proximity to the dock. After several attempts, the notching was completed at 1430. By 1450 the icebreaking operation commenced with an initial run inside the breakwater from the CCG dock to the Main Entrance. As torn sole pieces had been observed on the previous day's operation, they were monitored closely throughout the operation by means of the underdeck video camera. Additionally, speeds were kept below 4 knots.

By prior arrangement, airborne video coverage of the icebreaking operation was obtained through a local company, Monitor North, who chartered a light aircraft for the purpose. A very informative tape was made during the several passes of the aircraft over the ACIB/ALEXANDER HENRY.

The icebreaking operation continued until 0200 on 11 March. At 1900 the ACIB crew reported considerable damage to the sole pieces in the bow section of the ACIB. One sole piece was missing completely, one was retained by only a few centimeters of bonding at its inboard edge and several others had tears of varying length. However, insofar as could be determined there was little or no damage to the skirts themselves. The decision was made to continue with the operation since backing manoeuvres that could damage the skirts were not required.

During the latter stages of the operation, an interesting icebreaking phenomenon was observed. With the craft proceeding at a steady 4 knots in smooth snow-free ice 45 cm thick, a path 45 m wide was being broken. It appeared that the initial break was occurring along a bow wave formation.

2.8.5.3 OPERATIONS ON 10/11 MARCH 1983 (Cont'd)

At 0100 on 11 March, the ACIB Trials Engineer reported that additional damage to the sole pieces had occurred to the extent that virtually all of the pieces in the forward section were affected. He noted further that there appeared to be a small tear developing in one of the skirt segments. In his judgment, the operation could continue providing caution was exercised during any backing manoeuvre. As the current icebreaking objective had been met, the Master of the ALEXANDER HENRY opted to return to the CCG dock and de-notch the ACIB for beaching and a physical inspection of the skirts.

Evidently the icebreaking operations on 8, 9, 10 and 11 March were quite effective since a subsequent off-shore wind cleared out the ice in the harbour area outside the breakwater.

2.8.6 **Post-Test Inspection and Repairs**

On 11 March 1983, the ACIB was beached for an underdeck inspection of the skirt segments. For this purpose, the water ballast tanks were removed and replaced by 6 ballast blocks. The beaching operation proceeded without incident. The underdeck inspection was performed with the ACIB on hover and the Trials Engineer standing in a safe location under the craft near the inspection hatch. From this vantage point, he confirmed that at least 28 skirt soles in the forward section (Nos. 19 to 46) showed signs of damage ranging from one completely missing and one dangling by a 60 cm strip on one side through intermediate degrees of damage to three that showed no damage.

The subsequent above deck inspection revealed the following:

- The upper attachment bracket on No. 4 notch boom had failed in tension and the lower attachment weld was cracked. It was believed that this damage had occurred during the notching operation on 10 March.

2.8.6 **Post-Test Inspection and Repairs** (Cont'd)

- There were areas of wear about 10 by 30 cm opposite the top member of booms Nos. 4 and 5 about 1 m outboard of the carousel, a tear in the No. 4 segment flap over the broken attachment bracket and wear areas in the spray flaps.

- Nine D-rings were torn free and a retaining chain missing from the rub aprons.

- Two chain attachment plates were pulled out of the notch spray skirts as well as the lower section of the Port skirt being torn off.

- The weighted cable pouch was found to be worn through on both aft sections of the spray skirt.

A report on the damage was passed to the TDC and German & Milne Project Managers for a decision on the course of action to be taken. A requirement existed to perform an icebreaking demonstration with the ACIB for a Japanese delegation on 16 March and also to carry out open water trials with the craft before laying it up for the season. Since there was adequate ice inside the breakwater for the demonstration and open water outside the breakwater for the trials, it was decided that these tasks would be performed on successive days and that only the repairs essential to their accomplishment would be made.

It was agreed that all of the damage to the notch section would be repaired and that only a sampling of 5 of the skirt segments in the bow section would be removed for detailed inspection and repair. It was recognized that there was a potential for skirt snagging during backing if all skirts were not repaired, however, it was agreed that the speed of such manoeuvres would be kept below 2 knots.

2.8.6 **Post-Test Inspection and Repairs** (Cont'd)

The necessary work was carried out during the period 12 to 14 March. Of the five skirts (Nos. 32 to 36) removed from the bow section, two (Nos. 35 and 36) had only minimal wear. The other three had at least half of the curved joint between the sole and the skirt torn free at the bond plus some bond separation along the sides. Of the two adjacent skirts, Nos. 31 and 37, one had only minimal wear and the other had its sole torn free over the whole length of the bond except for a 60 cm strip on one side. This sole was removed completely and the skirt left as it was.

It was evident that the cause of the failures was due to poor bonding and not to the design of the closed sole. It was also evident that improvement in the manner of attachment of the sole piece was needed. In the original modification, the sole was bonded on the outside of the skirt along the sides and on the inside of the skirt in the curved section. The transition from outside to inside caused a bulge at the tangent points of the curved section which contributed to the wear and snagging. An improved method of skirt-to-sole attachment was employed on the 5 skirt segments that had been removed for repairs. The soles were stripped back about 60 cm from the curved section on either side and re-bonded with the sole material onthe inside of the skirt. Additionally, rivets with penny washers were affixed at the tangent points of the curved section.

During the removal of the five skirt segments, it was found that a support rod in one of them was bent. The fact that this rod had not pulled free of its supports attested to the effectiveness of the support bracket modifications. The rod was replaced with a steel section of like size since aluminium sections of this type were not available locally.

On 15 March following the completion of the emergency repairs, the ACIB was launched. The heavy snow cover in the lee of the dock made the launching operation difficult and again pointed up the need for increased power in the transit winches. The launch, however, was successfully accomplished. Subsequently, the solid trim ballast was removed and

2.8.6 **Post-Test Inspection and Repairs** (Cont'd)

replaced by the water ballast tanks. However, these were not filled for the notching operation. By having the stern of the craft high when on hover, the movement over the rough ice between the craft and the ship was facilitated and a successful notching was achieved.

2.8.7 **Icebreaking Demonstration**

In preparation for the demonstration which was scheduled for the afternoon of 16 March, the ACIB/ALEXANDER HENRY proceeded to break ice at the entrance to the CCG slip and around the adjacent docks during the morning. During this operation, all equipment was checked out and it was confirmed that backing operations could be done without snagging the skirts if done slowly.

During a two-hour period on the afternoon of 16 March, the demonstration was carried out. Ice of thickness up to 65 cm was broken in the vicinity of Pool 6, Pool 7A and the Ore dock. The effectiveness of the ACIB/ALEXANDER HENRY in performing such an operation was clearly demonstrated. Although considerable backing was involved, no observable additional damage was done to the skirts.

2.8.8 **Open Water Trials**

The objective of the open water trials on 17 March 1983 was to measure the change in trim angle and hover height as speed was increased and also to observe bow wave formation. Further the maximum speed achievable with the ACIB/ALEXANDER HENRY combination over water was to be determined for comparison with speeds achieved over ice.

Prior to commencing the over water trials, a 45-minute period was spent breaking ice around Pool 7A and the Ore dock.

2.8.8 **Open Water Trials** (Cont'd)

The open water trials were performed on a course parallel to the shoreline about 1.8 km off the breakwater. Runs at several shaft RPM increments were made on reciprocal headings to cancel the effect of wind. The maximum speed achieved was 7.4 knots. The trim angle increased from 1.3° nose up at low speed to 2.25° nose up at maximum speed. Hover heights increased slightly from 3.35 to 3.50 m. The detailed results are contained in Section 3.2.7.

2.9 LAY-UP

2.9.1 Termination

Following the completion of the over water trials, the Master of the ALEXANDER HENRY informed the ACIB project team that he had completed the work he intended to perform with the ACIB. It was therefore decided to beach the ACIB and terminate the operational phase of the 1982/83 evaluation.

2.9.2 Beaching Operation

Accordingly, the ACIB was beached on 18 March. In preparation for this operation, all 22 of the ballast blocks were positioned on the beaching pad in a pattern conforming to that of the buoyancy tanks of the ACIB. The craft was then winched, on hover, over the blocks and set down on them as it came off hover. This raised the level of the craft about 75 cm greatly improving access to the skirts for inspection and repair.

2.9.3 Inspection

A physical inspection of all of the skirt segments was made by the Trials Team. Although the increased height of the craft greatly facilitated underdeck movement, nevertheless, about 1 m of skirt material lay folded on the ground and it was necessary to enter each skirt segment and unfold it for inspection.

2.9.3 **Inspection** (Cont'd)

The inspection revealed that 20 of the 67 skirt segments were essentially intact. This included the five that had been repaired and modified during the 12 to 14 March emergency repair period. Of the remainder, 3 soles were completely missing, 19 had part of the semi-circular bonded joint at the toe of skirt separated and 25 had part or all of the joint separated plus additional separation up one or both sides of the sole-to-skirt joint.

The fact that the soles that had remained intact were randomly spaced around the craft and that essentially all of the sole separations could be attributed to bond failure led to the conclusion that the problem could be attributed to improper curing and/or quality control of the bonding process. It was recognized that at the time that the repairs and modifications were made in February, many of the segments were taken directly from the shop to the craft with minimum curing time because of the time constraints of the program. The problem was discussed at length with the Sub-Contractor involved, Rematech, and a formal request made to the company to carry out tests on the effects of cold soaking after minimum curing time. These tests were done and a report provided (Appendix B).

The Sub-Contractor's findings confirmed the Trial Team's assessment that early exposure to cold was a factor in the bond failures and also their judgment that a hot bonding process would yield a stronger joint than the cold process employed. A description of this process is also contained in Appendix B.

The post-season below deck inspection also included the spray aprons, wear aprons, notch segments, notch booms and pushing post. The results of this inspection and the above deck inspection are contained in the ACIB log book.

2.9.4 Close Out

The close out of the operational phase of the program included the following:

- Removal of the test instrumentation from the ACIB and the ALEXANDER HENRY and its return to the point of origin.
- An up-dating of the ACIB inventory and a physical check of the items.
- The closing out of local accounts.
- Removal of the sleeping trailer from the ALEXANDER HENRY and its return to the rental agency.
- Turning in the rental vehicles used by the Trials Team.
- Preparing a short video presentation from tapes made during the trials and showing it to interested parties.
- Clearing all loose equipment from the deck of the ACIB and storing it.
- Covering the notch segments with tarpaulins to minimize further ultra-violet deterioration of the segment material.

From 31 March 1983 onward (to a date determined later), the ACIB was left in the custody of the Trials Technician.

3.0 PERFORMANCE PARAMETERS

3.1 INTRODUCTION

In accordance with the Work Statement (Appendix A to Contract No. OSD82-00128), a test program was drafted and discussed at a meeting held at Thunder Bay on 14 December 1982. The amended document (Appendix C) was not formally approved, but was followed to the extent that circumstances and ice conditions permitted.

Since real time records were not required, it was decided, in the interests of reliability and cost, to use the simplest instrumentation commensurate with ease of use and accuracy.

As an exception, continuous records were taken of the speed of the shafts on either side of the fluid couplings in the ALEXANDER HENRY's propulsion units in order to obtain an indication of slippage across the coupling. This, besides giving an indication of the cause of previously experienced overheating, was also expected to show the frequency of ice strikes on the propellers.

During the program a distance of 250 km was covered in ice thicknesses ranging from 25 to 66 cm in 9 days of operations. Figure 15 shows the tracks of icebreaking runs made during the performance testing phase and Figure 16 the tracks made during the operational phase. The major events that occurred during these phases of the program are listed in Table 1.

A summary of the measured performance and a discussion of results follows.

The cushion pressures mentioned in the following sections are in centimetres of water gauge. The hover heights are the distances in metres from deck level to the ice, water or ground level as appropriate to the circumstances.

TABLE 1: SUMMARY OF EVENTS

DATE	EVENT
19 Jan 83	Checkout over land.
20 Jan. 83	Launched.
21 Jan. 83	Checkout over water. Static hover tests at 282.4 tonnes.
27 Jan. 83	Small vessel tests. Hover time: 8 hours. Icebreaking time: 4.5 hours. Distance: 23.1 km (12.5 nautical miles)
28 Jan. 83	Notching and functional checks with the ALEXANDER HENRY. Hover time: 6 hours. Icebreaking time: 2.5 hours. Distance 8.3 km (4.5 nautical miles)
31 Jan. 83	Icebreaking performance with the ALEXANDER HENRY. Hover time: 4.75 hours. Icebreaking time: 4 hours. Distance: 25.9 km (14 nautical miles)
1 Feb. 83	Icebreaking performance with the ALEXANDER HENRY. Hover time: 10 hours. Icebreaking time: 9.25 hours. Distance: 63.0 km (34 nautical miles)
2 Feb. 83	ACIB beached for repairs to skirt soles.
24 Feb. 83	Static hover tests over land. Clutch failed.
3 Mar. 83	ACIB launched.
4 Mar. 83	ACIB ballasted to 264 tonnes.
7 Mar. 83	ACIB notched with the ALEXANDER HENRY and hover tests performed.
8 Mar. 83	ACIB/ALEXANDER HENRY operational trials. Hover time: 8 hours. Icebreaking time: 7 hours. Distance: 22.2 km (12 nautical miles)
9 Mar. 83	ACIB/ALEXANDER HENRY operational trials. Hover time: 6 hours. Icebreaking time: 3.6 hours. Distance: 25.9 km (14 nautical miles), (197 tonnes)
10 Mar. 83	ACIB/ALEXANDER HENRY operational trials. Hover time: 15 hours. Icebreaking time: 11.5 hours. Distance: 72.3 km (39 nautical miles)
11 Mar. 83	ACIB beached for inspection and essential repairs.
15 Mar. 83	ACIB launched and notched with the ALEXANDER HENRY.
16 Mar. 83	ACIB checkout moving astern. Hover time: 1.75 hours. Icebreaking time: 1.0 hours. Distance: 1.85 km (1.0 nautical miles). ACIB/ALEXANDER HENRY icebreaking inside the breakwater (66 cm ice). Hover time: 2.5 hours. Icebreaking time: 2.0 hours. distance 4.4 km (2.4 nautical miles)
17 Mar. 83	ACIB/ALEXANDER HENRY icebreaking in the harbour and open water tests. Hover time: 6.5 hours. Icebreaking time: 1.0 hours. Distance over ice 3.7 km (2.0 nautical miles). distance over water 20.4 km (11.0 nautical miles).

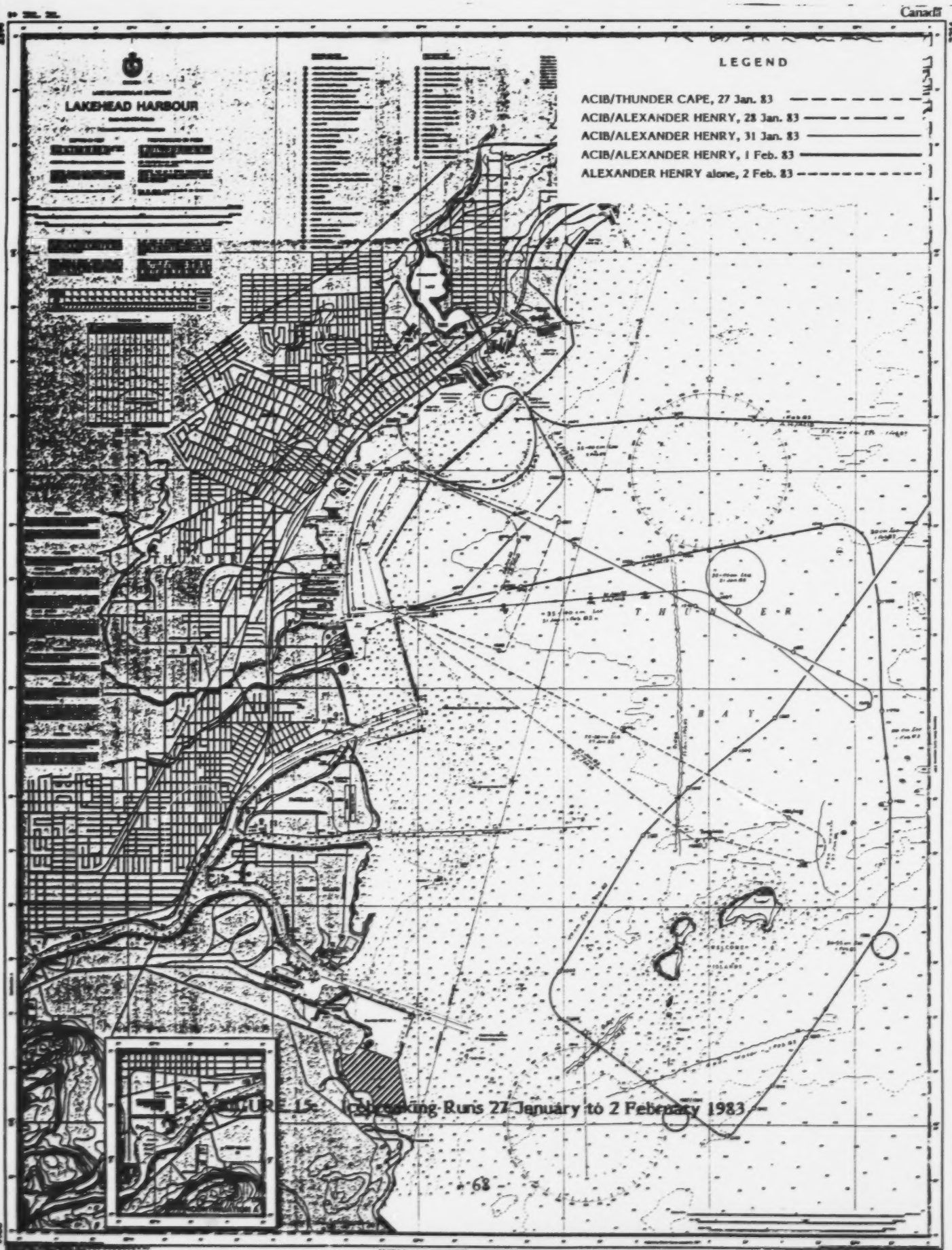


FIGURE 15: Icebreaking Runs 27 January to 2 February 1983

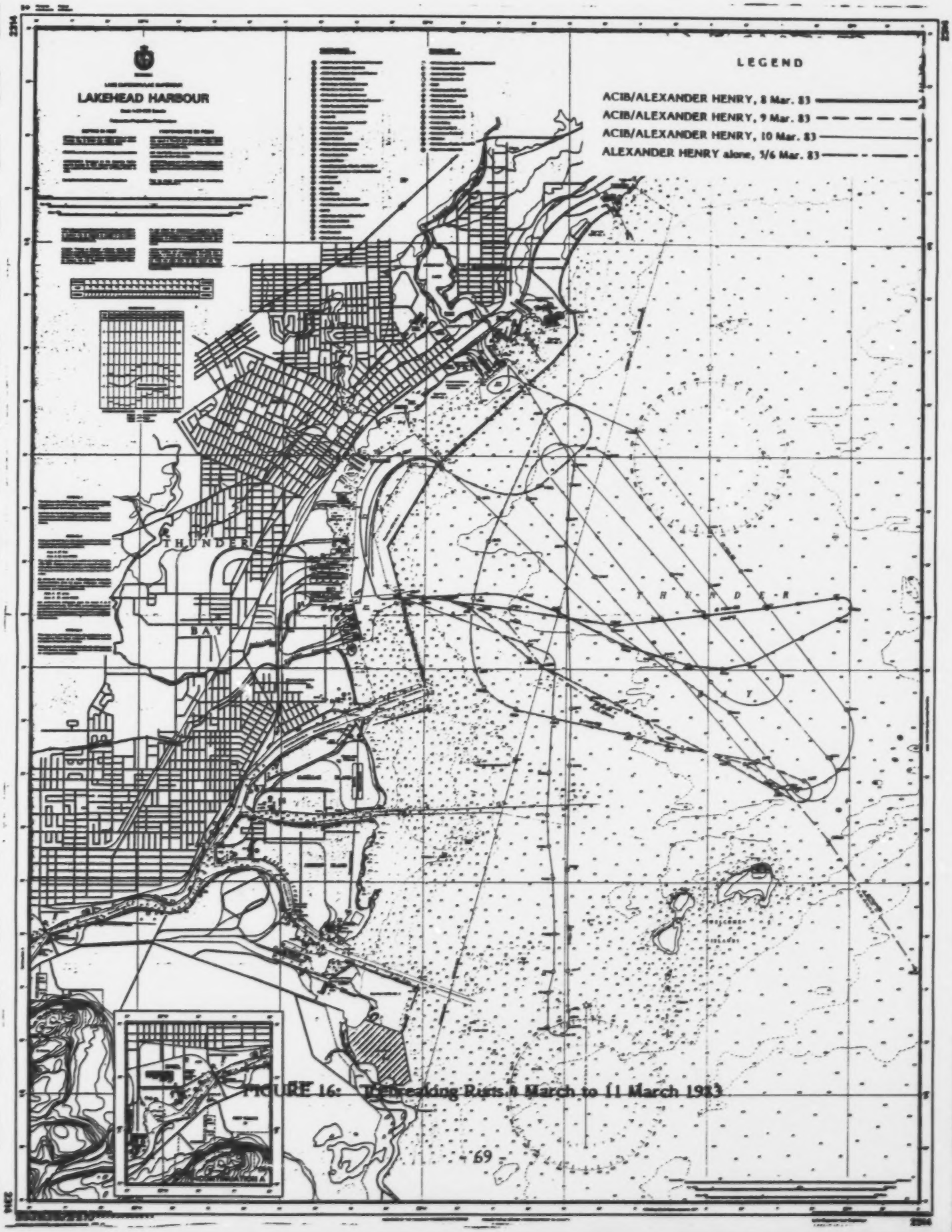


FIGURE 16: Icebreaking Runs 8 March to 11 March 1983

3.2 TEST RESULTS

3.2.1 Test Objectives

In addition to providing the crew of the ALEXANDER HENRY with experience in operating the ACIB, certain performance parameters of the ACIB/ship combination were to be measured. These were:

- o Ship's propeller shaft RPM versus speed
- o Turning radius capability in ice of various thicknesses
- o Width of the broken path and size of the ice pieces
- o Change in ACIB trim versus speed
- o Fuel consumption
- o Open water performance

Tests on the ACIB alone were also required to determine:

- o Hover height and trim angles versus cushion pressure
- o Freeboard versus ballast weight

3.2.2 Shaft RPM Versus Speed

The shaft RPM versus speed data was obtained as an intermediate step in determining the thrust required to propel the ACIB at various speeds. The thrust determinations will be made from the results of future bollard pull tests in which the ship's thrust and shaft RPM will be measured under varying load conditions. This information will be combined with the shaft RPM/speed data obtained during the ACIB trials to provide the required thrust/speed curves.

The shaft RPM and speed data obtained during the trials are tabulated in Table 2 together with information on ice conditions, path width and piece size.

The speed of the ACIB/ship combination was highly sensitive to snow cover, ice thickness, wind velocity and cushion pressure. The combined effect of snow cover and ice thickness was particularly evident in passing

Date	Ship	ICE		SHIP		ACIB				PATH		TEMPS		REMARKS
		Thickness (cm)	condition	Shaft RPM	Speed (K)	Weight (T) c.of g. (m) *	Eng. RPM	Cushion Press. (cm)	Hover Height (m)	Width (m)	Piece Size (m)	Air (°C)	Water (°C)	
27 Jan.	THUNDER CAPE	35	Clear with scattered snow patches	155 175 185 197	3.0 3.5 4.5 5.4	210 x: 0.0 y:0.47	1600	71.0	3.50	30	2.5	-12	0	
		75	Ridge - snow covered	180	4.0/ 1.5					27	3.0			Slowed but not halted by ridge.
		65	8 cm snow cover	155 185 197	1.5 2.5 3.0					27	3.0			
31 Jan.	ALEXANDER HENRY	35	10 cm new snow	100/100 150/150 210/210 220/225 225/230	1.2 2.5 4.5 5.4 5.9	201 x: 0.0 y: 0.78	1600	71.0	3.45	30 36	2.5 2.0	-7	0	
		65	8 cm old 10 cm new snow	210/215	3.0			69.5	3.40	30	3.0			
1 Feb.		40	10 cm snow	100/100 150/150 200/200 224/228	1.4 2.5 4.3 5.3	201 x: 0.0 y:0.78	1600	75.0 72.0	3.35 3.25	30 36	2.5 2.0	-11	0	
		50 to 75	Ridge - snow covered	150/150	2.0/0			73.5	3.25	27	3.0			Halted by ridge.
8 Mar.		50	Water covered	145/150 170/175 210/225	1.5 2.3 3.5	263.7 x: -0.26 y: 0.74	1800	92.5	2.95	30	3.0	+2	+3/4	
				220/230	4.2			85.0	2.45	36	3.5			Ice strikes on craft structure.
		65	Water covered	210/225	3.5			89.0	2.90	33	3.0		+1.0	
9 Mar.		50	Snow patches over clear ice.	190/195 190/195 225/225	5.4 4.2 6.5	199.7 x: -0.05 y: 0.73	1600	70.0 71.0	3.50 3.50	33 36	2.5 2.0	-9	+1.0	Following wind Head wind
		65	Frozen snow cover	215/220	4.3			68.5	3.40	30	3.0			
10/11 Mar.		50	Snow patches over clear ice	170/175 180/185 190/195	3.0 3.5 4.5	199.7 x: -0.05 y: 0.73	1600	68.5	3.40	33 45	3.0 2.5	-5	+1.5	
16 Mar.		65	Frozen snow cover	150/160	2.0	199.7 x:-0.05 y: 0.73	1600	72	3.40	30	3.5	+1		

* Centre of Gravity: Refrence - Geometric Centre. X: Port/Starboard, Port Positive
Y: Fore/Aft, Forward Positive

TABLE 2: Icebreaking Performance Summary

3.2.2 **Shaft RPM Versus Speed** (Cont'd)

over ridges where drifted snow had reached a depth of 30 to 60 cm and ice thickness approached or exceeded the cushion pressure. In one instance when the ACIB/ALEXANDER HENRY approached such a ridge at slow speed (2 knots) the craft was brought to a halt. In a similar instance with the ACIB/THUNDER CAPE, the craft was slowed from 4.0 to 1.5 knots. Also, minor variations in speed were noted as the craft passed from clear ice onto patches of snow. The effect of ice thickness alone on speed was apparent when comparing speeds obtained in 66 cm ice inside the breakwater with those obtained in thinner ice outside the breakwater. At comparable shaft speeds and cushion pressures, speed differences of up to 2 knots were recorded. However, reliable speed determinations inside the breakwater were difficult to obtain because of the short lengths of the runs and the lack of undisturbed ice. Frequent passages along the channels inside the breakwater had left a jumble of ice.

The effect of wind velocity was observed on runs with the ACIB/ALEXANDER HENRY on reciprocal headings at constant shaft RPM. With a following wind of 5 to 10 knots, a speed of 5.4 knots was achieved at shaft speeds of 190/195 RPM. On the reciprocal course, heading into wind, the speed was 4.2 knots.

The effects of ACIB weight and cushion pressure on speed was observed during operations on two successive days in ice of comparable thickness and surface condition. On the first day the craft was operated at its maximum authorized weight of 264 tonnes and a cushion pressure of 90 cm. On the second day, the weight was 200 tonnes and the cushion pressure 70 cm. The speeds achieved in the heavy weight, high cushion pressure condition were approximately 2 knots lower than those achieved in the light weight, moderate cushion pressure condition.

3.2.2 **Shaft RPM Versus Speed** (Cont'd)

When operating in 50 cm ice in the heavy weight condition with cushion pressures of the order of 90 cm, a marked decrease in cushion pressure occurred when the speed was increased to 4 knots. At this speed, the ice sheet was extending under the craft far enough and high enough to strike its structure near the sides of the buoyancy tanks. It appeared from the underdeck video camera coverage that the intact ice sheet was rising as it moved further under the craft. (Figure 17 shows the type of video coverage obtained on this occasion). In the interest of safety, it was necessary to keep the speed below 3 knots for the remainder of the day's operation.

FIGURE 17: Underdeck Video Camera Coverage

3.2.2 **Shaft RPM Versus Speed** (Cont'd)

The maximum speed achieved during the icebreaking trials was 6.5 knots. This occurred operating with the ALEXANDER HENRY in predominantly clear ice, 50 cm thick. The practical speed of icebreaking in comparable ice conditions was considered to be about 4 knots. At higher speeds, it was felt that skirt wear would be markedly accelerated, however, insufficient testing was done to confirm this. At lower speeds, there was a tendency to be slowed excessively as the craft encountered areas of drifted snow or other surface irregularities. Further, at low speed there was an increased amount of spray as described in the following section.

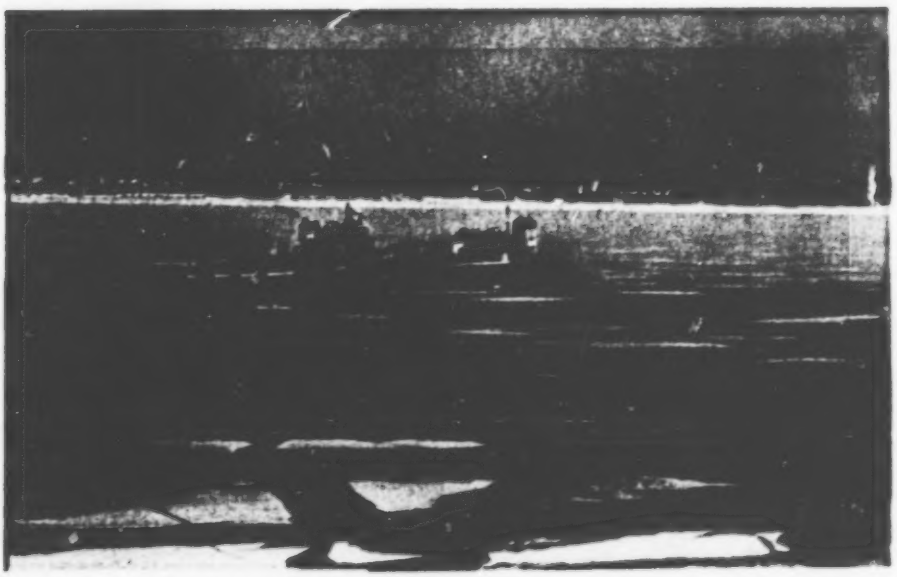


FIGURE 18: ACIB/THUNDER CAPE Turning Circle

NOTE

Arctec Canada Limited FR-582B Final Report on the Winter Trials of CCGS ALEXANDER HENRY 1980, submitted to Canadian Coast Guard, states that "the average speed of the ship advancing through ice was 0.19 knot." The ice thickness is not given but the report also states that "the ice thickness ranged from ---- 23 in to 30 in" (58 to 76 cm - averaging 67 cm). The ship was, of course, advancing in the ramming mode.

In 65 cm of ice, the ACIB/ALEXANDER HENRY combination was able to proceed at steady speeds up to 4.3 knots, dependng on shaft rpm. This represents an increase in speed of advance by a factor of 20 plus.

3.2.3 Shaft RPM Versus Speed (Cont'd)

Sufficient data has not been obtained to make a comparison at ice thicknesses from 0 to 1 metre, but it may be assumed that in open water the ALEXANDER HENRY will be faster, that the curves will cross somewhere below 28 cm (11 in) of ice (Arctec report and 1982/83 trials) and that the advantage of the ACIB/ALEXANDER HENRY combination will increase rapidly from this point.

A general statement that the icebreaking performance of the ALEXANDER HENRY is improved by a factor of 10, an order of magnitude, when combined with the ACIB is considered to be conservative.

3.2.3 Path Width and Piece Size

At no time during the trials was the width of the broken track less than the width of the ACIB. Minimum path widths occurred at slow speeds in the 60 to 66 cm ice encountered inside the breakwater. Under these conditions, the average path width was 30 meters. The maximum path width occurred during sustained runs at 4.2 knots in smooth, relatively snow-free undisturbed ice 50 cm thick. The width achieved was 45 m with the initial fracturing of the ice occurring along a line comparable to a bow wave.

At slow speeds, the initial fracturing occurred ahead of the craft. As speeds reached 4 to 5 knots, breaking occurred inside the skirts. This resulted in a marked decrease in the spray in the bow area.

The size of the broken pieces varied widely. At low speeds in the 60 to 66 cm ice, the major dimension of the larger slabs was as much as 3.5 m. At higher speeds in 30 to 35 cm ice, the piece size was of the order of 1.5 to 2.0 m. Throughout the trials the ice remained relatively brittle even though the air temperature rose above 0°C on occasion. A marked decrease in piece size occurred when passing over previously broken and refrozen tracks.

An indication of the general breaking pattern is provided in Figure 19 which shows the undisturbed slabs of ice that were left in place as the ACIB/ALEXANDER HENRY came to a stop in front of the Ore Dock and backed away.

FIGURE 19: Pattern of Initial Breaking of 66 cm Ice

3.2.4 Turning Radius

Turning radius tests were performed with the ACIB/THUNDER CAPE and the ACIB/ALEXANDER HENRY. The turning performance of the ACIB/THUNDER CAPE was particularly impressive (see Figure 18). In 40 cm ice, its turning radius was 25 metres - equivalent to the width of the ACIB. This capability would be of particular value in icebreaking operations in and around the harbour slips.

The initial turning radius tests with the ACIB/ALEXANDER HENRY were performed in 40 cm ice with subsequent checks in 50 cm ice. Meaningful tests in the thicker ice inside the breakwater could not be performed because of the limited width of the navigable channel.

The ACIB turning radius with both engines at full speed and the rudder hard over was 600 metres. The turning radius with one engine stopped, the other at full speed and the rudder hard over was 185 metres. As a comparison, the open water turning radius was checked. With both engines at full speed and the rudder hard over, the radius was 185 metres.

3.2.5 Trim Angle Versus Speed

Very little change in trim angle was observed during the icebreaking trials as speed was increased. Over the speed range of 0 to 5 knots, the change was +0.5° (nose up). Similarly, the trim angles measured during the open waer trials showed little change over the speed range of 0 to 5.5 knots, however, a +1.0° (nose up) change occurred as the speed was increased from 5.5 knots to 7.4 knots.

Ice Conditions: 40 cm thick, 10 cm snow cover

SHAFT RPM		SPEED	DIST. TRAVELLED	FUEL CONSUMPTION (l)			FUEL (l/km)
P	S	(knots)	(km)	Ship	ACIB	Both	Both
100	100	1.4	0.83	36.4	70.9	107.3	128.5
150	150	2.5	1.54	50.0	83.2	133.2	86.5
200	200	4.4	3.26	113.6	100.0	213.6	65.5
224	228	5.3	5.93	222.7	141.8	364.5	61.5
200	200	4.1	3.15	122.7	100.0	222.7	70.7
150	150	3.2	1.48	36.4	62.3	98.7	66.7
220	220	4.7	6.58	295.5	187.3	482.8	73.4

TABLE 3: Fuel Consumption vs Speed - ACIB/ALEXANDER HENRY

DATE	ICE CONDITIONS	DIST. TRAVELLED (km)	FUEL CONSUMPTION (l)			FUEL (l/km)
			Ship	ACIB	Both	Both
31 Jan. 83	30-35 cm thick 10 cm snow	25.9	1,064	818	1,882	72.7
2 Feb. 83	40 cm thick 10 cm snow	1.1	441	(A.H. alone)		397.0
5/6 Mar. 83	25-50 cm thick 10 cm snow	12.0	10,442	(A.H. alone)		870.0
8 Mar. 83	50 cm thick water covered	22.2	973	1,500	2,473	111.4
9 Mar. 83	50 cm thick snow patches	25.9	1,027	955	1,982	76.5
10 Mar. 83	50 cm thick snow patches	72.3	2,728	2,750	5,478	75.8

TABLE 4: Average Fuel Consumption - ACIB/ALEXANDER HENRY

3.2.6 Fuel Consumption

Fuel consumption runs were made with the ACIB/ALEXANDER HENRY on 1 February 1983 for the purpose of determining the optimum speed of operation insofar as fuel economy was concerned. The results of these runs are tabulated in Table 3. Additionally, fuel consumption records were maintained on all of the other trial runs with the ACIB/ALEXANDER HENRY and on two runs with the ALEXANDER HENRY alone. These results are contained in Table 4.

Evidently, significant savings in fuel costs could be made by employing the ACIB in icebreaking operations; however, of perhaps greater significance is the speed with which such operations can be performed and also the marked reduction in wear on the ship's engines, fluid couplings and hull as compared to icebreaking operations alone. Alternatively, even greater savings could be realized by employing a smaller craft such as the tug THUNDER CAPE as the motive vessel.

3.2.7 Open Water Trials

The open water trials were performed to determine the performance characteristics of the ACIB/ALEXANDER HENRY when operated under conditions that would prevail in moving the craft from one base of operations to another. Of particular interest was the maximum practical speed of operation and any change of cushion pressure, hover height and trim that would occur as speed was increased. As mentioned in Section 2.6.2.3, changes in trim angle were minimal. Similarly, only minor changes in cushion pressure and hover height occurred. The results of the tests are contained in Table 5. At the maximum speed attained (7.4 knots), no adverse performance characteristics such as porpoising were encountered. As shown in Figure 20, the bow wave formation at this speed was not pronounced.

SHIP		A C I B					WATER
SHAFT	SPEED	WEIGHT	ENGINE	CUSHION PRESSURE	HOVER HEIGHT	TRIM ANGLE	DEPTH
RPM	(knots)	(tonnes)	RPM	(cm)	(m)	(fore/aft)	(m)
100/100	3.0	199.7	1600/1600/1600	70.5	3.45	+1.3°	18.9
120/120	3.6			71.0	3.40	+1.3°	20.4
150/150	4.4			71.0	3.50	+1.3°	20.7
180/180	5.6			71.0	3.45	+1.3°	25.0
210/210	6.6			71.0	3.45	+1.8°	26.5
230/230	7.4			71.0	3.45	+2.25°	21.0
150/150	4.4		1600/1600/0	69.9	3.40	+0.7°	20.4

TABLE 5: Open Water Trials - Test Results

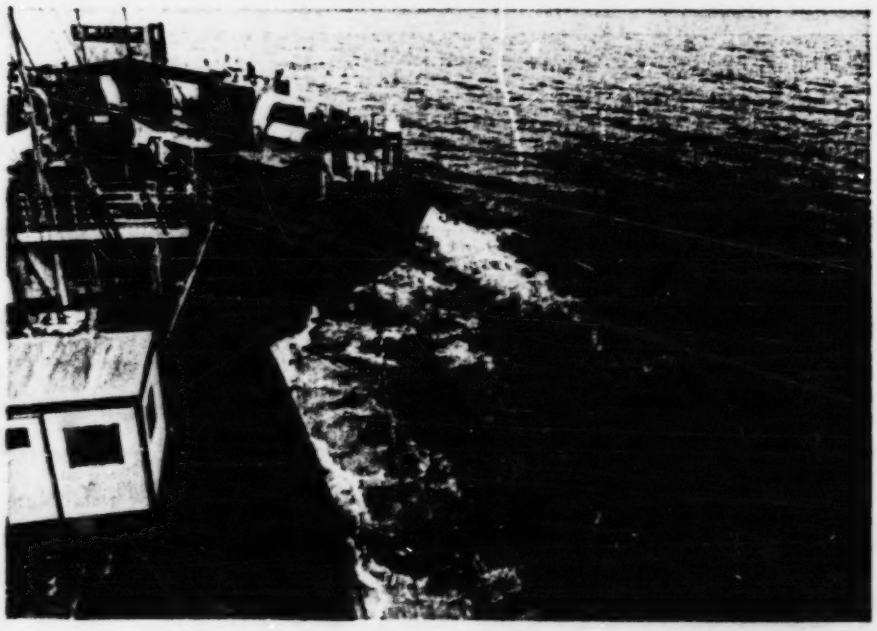


FIGURE 20: ACIB/ALEXANDER HENRY Bow Wave in Open Water

Date	Test Conditions		One Engine				Two Engines				Three Engines			
21 Jan. 83	Checkout over water (ice) Wt: 282.4T	RPM Cush. Press. Hover Ht. Trim - F/A - P/S	1200 52.8 1.07 -3.4° +0.5	1500 71.1 1.83 -2.5° 0	1800 75.2 2.19 -1.6° 0	2100 75.7 2.26 -1.6° 0	1200 63.2 1.31 -3.4° +0.5°	1500 81.0 2.56 -1.6° +0.5°	1800 84.6 2.80 -1.6° +0.5°	2100 93.0 2.83 -1.6° +0.5°	1200 58.9 1.37 -2.5° 0	1500 80.5 2.53 -1.6° 0	1800 87.4 2.99 -2.3° 0	2100 88.1 3.17 -1.6° 0
27 Jan. 83	Hover Test - Notched to Thunder Cape Wt: 210T	RPM Cush. Press. Hover Ht. Trim - F/A - P/S									1200 45.7 2.10 +0.5° -1.0°	1500 73.7 3.32 +1.5° -1.0	1800 76.2 3.50 +1.5° -1.0°	
28 Jan. 83	Hover Test - Notched to Alexander Henry Wt: 201T	RPM Cush. Press. Hover Ht. Trim - F/A - P/S									1200 47.0 2.04 +1.0 0	1600 73.7 3.35 +0.7° 0	1800 76.2 3.41 +0.7° 0	
25 Feb. 83	Checkout Over land after repairs Wt: 219.8T	RPM Cush. Press. Hover Ht. Trim - F/A - P/S	1200 57.9 2.50 -1.0° -0.5°	1350 71.1 3.54 -1.7° -0.5°	1500 72.4 3.60 -1.7° -0.5°	1800 74.4 3.78 Some Heave	1200 57.2 2.62 -1.5° -0.5°	1400 66.8 3.26 -2.0° -0.7°	1500 71.1 3.57 -1.6° -0.5°	1600 74.2 3.69 -1.5° -0.5°	1200 43.4 2.56 -1.0° -0.5°	1400 57.2 3.11 -2.0° -0.5°	1500 71.6 3.63 -2.0° -1.0°	1600 H E A V E
7 Mar. 83	Checkout over water (ice) Wt: 272.8T	RPM Cush. Press. Hover Ht. Trim - F/A - P/S						1500 67.3 1.07 -3.5° +2.0°	1800 82.6 2.44 -2.5° +0.7°	2000 83.0 2.50 -2.7° +1.2°	1200 54.6 0.94 -3.4° +0.5°	1600 72.4 2.10 -2.7° +0.2°	1800 84.6 2.71 -2.7° +0.5°	2100 85.1 MILD HEAVE
7 Mar. 83	Hover Test - Notched to Alexander Henry Wt: 263.7T	RPM Cush. Press. Hover Ht. Trim - F/A - P/S			1600 74.9 2.07 +0.5° +0.7°	1800 80.3 2.38 +0.5° +0.7°	1200 41.9 0.82 +1.5° +1.5°	1400 62.2 1.22 +0.3° +1.5°	1600 72.9 1.98 +0.3° +1.0°	1800 88.9 2.77 +1.5° +0.7°	1200 49.0 0.91 +0.7° +1.5°	1400 64.0 1.22 +0.2° +1.5°	1600 77.7 2.10 +1.2° +0.7°	1800 91.2 2.87 +1.5° +1.2°
17 Mar. 83	Hover Test - Notched to Alexander Henry Wt: 199.7T	RPM Cush. Press. Hover Ht. Trim - F/A - P/S						1600 67.3 3.35 +0.7° 0			1200 47.0 2.04 0.7° 0	1600 71.1 3.38 +0.5° 0	1800 74.9 3.47 +0.5° 0	

Cushion Pressure - cm
Hover Height - m, deck to ice (ground) surface
Trim - Fore/Aft, + = nose up
- Port/Starboard, + = Port up.

TABLE 6: Static Hover Tests

3.2.8 Static Hover Tests

Static hover tests were performed over land, over water alone and over water notched to the ALEXANDER HENRY and to the THUNDER CAPE. The tests were performed as a functional check of the ACIB equipment and to measure its hover performance under various weight conditions and engine operating speeds. The results of the tests are given in Table 6.

Of particular interest is the craft's one and two engine hover capability. Evidently, the ACIB is capable of sustained operation in the light weight condition on two engines and may be capable of short term operation on one engine.

3.2.9 Freeboard Versus Ballast

Freeboard versus ballast measurements were made on 4 March 1983 as ballast was being loaded aboard the ACIB in preparation for the heavy weight hover tests and subsequent icebreaking operations. The results are given in Table 7.

WEIGHT (tonnes)		C. of G.		Freeboard	TRIM (°)	
Ballast	Total	X (m)	Y (m)	(m)	F/A	P/S
0	187.5	0.0	0.83	1.02	-1.0	-1.0
16.3	203.8	-0.04	0.71	0.94	-0.5	-1.0
32.3	219.8	-0.08	0.70	0.88	-0.5	-1.0
44.3	231.8	-0.09	0.76	0.82	-0.5	-1.0
52.3	239.8	-0.20	0.71	0.76	-0.5	-0.7
60.4	247.9	-0.26	0.70	0.71	-0.5	-0.5
76.2	263.7	-0.26	0.74	0.58	-0.5	-0.5

CENTRE OF GRAVITY: X - Port/Starboard, Port Positive
Y - Fore/Aft, Forward Positive

TABLE 7: Freeboard vs. Ballast Weight

3.2.10 Shaft RPM

As indicated in para 3.1 and Appendix A, a monitoring system was installed in the Engine Room of the ALEXANDER HENRY to monitor the engine and propeller shaft RPM. In the event the data obtained from the system was not particularly satisfactory, largely because of a scale problem, particularly on the time base, which made the strip chart difficult to read. However, the following should suffice to indicate the saving in wear and tear on the propulsion system when the ACIB is used.

Figures 21 and 22 are typical of the strip chart records. The uneven running due to trouble with the starboard fluid coupling is readily apparent.

Figure 21 shows data recorded on 10 March when the ACIB/ship combination was proceeding at 4-5 knots in 50 cm ice with snow patches. The smoothness of the port power train is quite evident (Channel D). Over the period of the record (nearly 3 hours) the largest Δ detected on the port side was at 03:10:17:41:37, which was 25 RPM and had a duration of about 20 s. Obvious Δs due to changes in ERPM have been ignored. The starboard side records are not interpretable.

Figure 22 shows data recorded on 4 March when the ship alone was ramming in ice varying from 60 to 30 cm with about 12 cm of snow cover. Over the period of this record (nearly an hour) the roughness of the ramming operation is clearly demonstrated, and there are significant Δs not associated with reversals, which are taken to indicate ice strikes. The highest values of Δ recorded are +107 RPM (forward) for 31 s and -63 RPM (reverse) for 36 s.

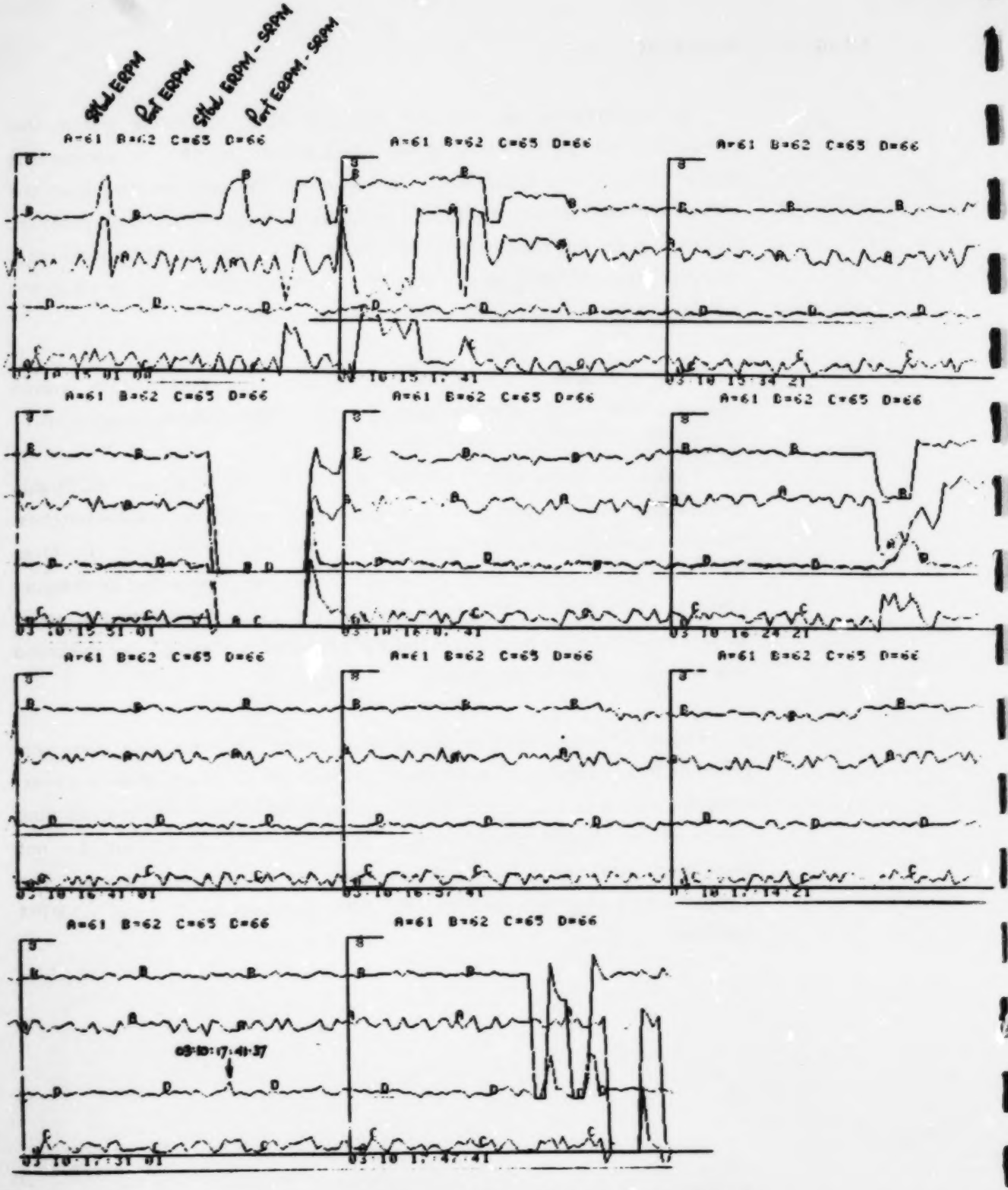


FIGURE 21: RPM Records, ACIB/ALEXANDER HENRY

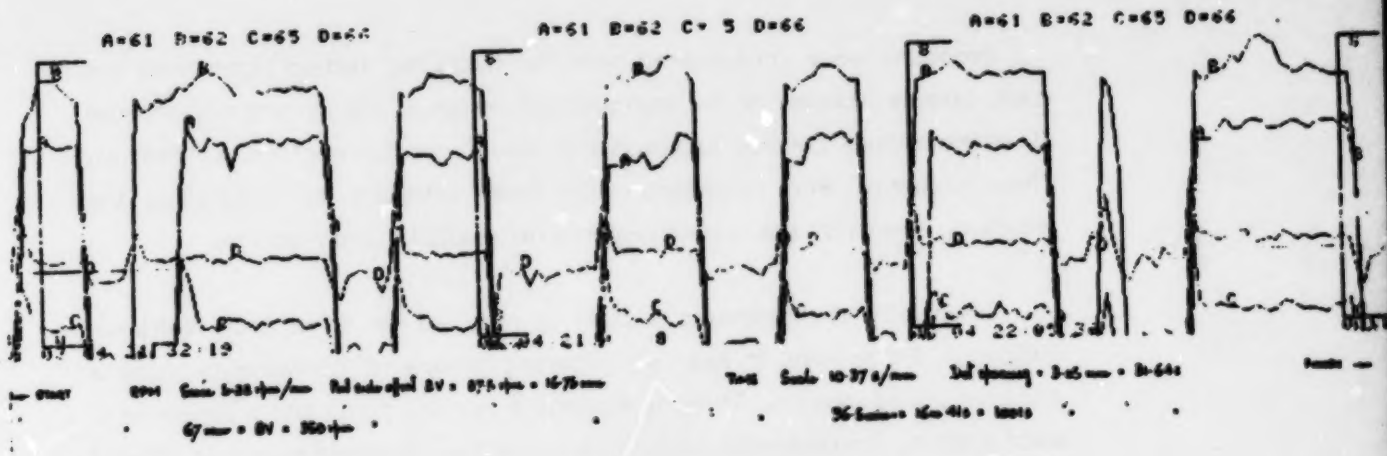


FIGURE 22: RPM Records, ALEXANDER HENRY Alone

3.3 TECHNICAL OBSERVATIONS

3.3.1 Electrical System

The ACIB was designed originally for unmanned operation and the electric requirements were minimal and confined to 24V DC from the electric systems of the main engines. Requirements for over and under deck lighting, power outlets for instrumentation and tools, and heating have introduced 110 and 220V AC circuits on a very haphazard basis, with inputs from hydro and, from time to time, a variety of rented portable generating sets.

There is on board at present a 75 kW 220V AC 3 phase diesel generating set provided by CCG, the capacity of which grossly exceeds any foreseeable requirement. However, it is there and the time is opportune to rationalize the electrical system to a standard 110/220V AC. In particular, circuits should be divided to ensure, for example, that all Control Room lighting is not on the same circuit. Cannon connectors should be used on all wiring (electrical and communications).

3.3.2 Hydraulic System

Problems were encountered with the hydraulic system right from the start, largely because of the complicated design of the system and the use of oversensitive control valves which could not be kept in adjustment. These problems were overcome with fixes adequate to completing the program. However, the system requires rationalizing and redesign.

Essentially the hydraulic system is required to drive four hydraulic winches. At present it has two separate groups of components using a common piping system. There is a pump, a priming pump and a reservoir in each system, the reservoirs being interconnected. A single reservoir located to provide an adequate head to the main pumps would eliminate the need for priming pumps. In addition, the main pumps should have clutches so that when one pump is selected, the other will be off, and when the winches are off, both pumps may be turned off and the winches locked. This is a safety measure as well as reducing pump wear.

3.3.3 Liquid Ballast

To achieve a range of cushion pressures it is necessary to ballast the ACIB between its tare and maximum weights. To date this has been done with concrete blocks weighing about 4,000 kg each. A crane at $100/hour is required to make ballast changes and the blocks occupy deck space which could be used for other purposes. Furthermore, the blocks cannot be jettisoned in emergency situations or for reducing weight in event of skirt damage while operating. The alternative is liquid ballast. The ACIB is provided with three rectangular metal buoyancy tanks having a total displacement of about 150 m^3 (or 120 tonnes of fuel) which is ample to provide space for the required liquid ballast.

3.3.3 **Liquid Ballast (Cont'd)**

Trim ballast is carried at present in two 1,000 gal. (4546 litre) tanks. Water is pumped in and out over the side and the tanks are heated by blowing hot air into canvas shelters which cover them. This is complicated and time consuming. These tanks should be removed and replaced with equivalent underdeck fuel tanks located as far aft as possible. Careful design could reduce the size of the tanks. Trim adjustments would be made by transferring fuel between main and trim ballast tanks, the overall weight remaining constant.

Conversion to liquid ballast is strongly recommended.

3.3.4 **Icing**

Over deck icing is seen as a possible hazard and will be catered for by suppressive measures and covers. Underdeck icing, however, is a hidden problem.

Inspection under the deck after operations revealed very heavy ice build-up on the bottoms of the buoyancy tanks and on structural members. This ice was 15 cm thick in places and its weight was estimated to be at least 25 tonnes.

The build-up may not prove to be a significant problem but it is one about which CCG should be aware so that periodic checks may be made after operating for extended periods in very cold conditions. It may also give rise to a decrease in hover height and to nose down trim change.

3.3.5 **Skirt**

The basic design of the skirt system is good and the wear encountered to date has been minimal. The material is satisfactory and repairs can be carried out locally provided adequate curing time is allowed. Permanent repairs in situ cannot be made at low temperatures using available techniques.

3.3.5 Skirt (Cont'd)

- **Notch Segments.** The notch segments were virtually rebuilt for the 1982/83 season and careful attention was paid to the geometry. As a result they inflated and operated extremely well. Some damage occurred because both the THUNDER CAPE and ALEXANDER HENRY were notched right into the bumper which took them beyond the wear apron. Other damage was due mainly to deterioration of the material.

- **Straight and Curved Segments.** These segments were all refurbished to 1981/82 configuration with sole plates and trailing flaps. There was no trouble whatever with the primary segments and the new attachment fittings eliminated problems previously experienced. The performance of the aft straight segments was satisfactory, only slight damage occurring to the trailing flaps and sole plates. On the curved and forward straight segments, however, there was a great deal of damage to trailing flaps and sole plates, all of which occurred in forward motion when the flaps and sole plates are not performing any useful function.

  After some consideration of the requirement for flaps and sole plates on the curved and forward straight segments, the prudent decision to make repairs was made. Flaps were tucked in and bonded on all segments. This was not successful due to poor bonding. However, it is now considered that a fully closed sole with good drainage is the right way to go. Sole plates should be bonded inside on forward segments and outside on aft segments. The side corner segments probably do not require sole plates.

- **Spray Apron.** After increasing the top gap to overcome an icing problem, the spray apron was effective and trouble free. It is expected that spray suppression can be further improved by adding a flap over the top gap and/or by adding flap covered vents on the apron face.

- **Wear Apron.** This was generally satisfactory but needs to be extended to the full depth of the notch (see Notch Segments).

3.3.6 Handling

In general, ACIB handling was simple and straighforward but the minor problems encountered will recur if preventative action is not taken.

- **Fairleads.** The roller fairleads must be replaced by Port Colborne fairleads which will permit handling over a much wider range of angles. The location of fairleads must be changed to avoid damage by hauling over the deck edge.

- **Transit Winches.** The build-up of ice adjacent to the Coast Guard dock was such that power available from the transit winches was barely adequate. Since the pressure setting is related directly to cable diameter, this means that the cable diameter must be increased. An increase from 0.75" to 1.0" cable is recommended.

- **Docking Slipway.** The slipway is not uniformly graded and does not drain properly. This permits pools of water to form, into which skirt segments can freeze. Unnecessary time and effort was expended on the task of freeing skirt segments. The slipway must be graded.

  Ballast blocks were used to form a platform to raise the height of the ACIB when off cushion and facilitate underdeck maintenance. This is very satisfactory but the platform must be located sufficiently far up the slipway to permit the ACIB to be beached in front of them in case of loss of hover height.

3.4 AN ACIB FOR ARCTIC ICE

Because the operating conditions appear to be so different, it is difficult to make any projection from the ACIB trials at Thunder Bay to the expected performance of a larger ACIB operating in Arctic ice, although certain qualitative deductions can be made. For example, the most important parameter will undoubtedly be mechanical reliability, followed by provision for carrying out maintenance, such as skirt segment replacement, away from base facilities and under Arctic winter conditions.

3.4 AN ACIB FOR ARCTIC USE (Cont'd)

With the data available from studies concerning the transportation of oil and LNG from the Arctic, it should be possible to write a preliminary scenario for an Arctic Class ACIB, and take a first cut at such items as ice thickness, ice strength and structure clearance height, which would allow an initial specification to be drawn up, and some idea of the magnitude of the problem obtained. In particular, the characteristics of ice ridges must be considered.

It is suggested that a small project to prepare a scenario for an Arctic Class ACIB, including the parameters which would determine footprint dimensions, cushion pressure and hover height, could be very useful in establishing the relationship between Great Lakes and Arctic operations, and indicating likely problem areas.

With this information, it should be possible to design appropriate model tests in order to assess behaviour in ridged ice.

A search for areas in the Gulf of St. Lawrence where similar ridges to those encountered in the Arctic, but on a smaller scale, might be found, would also be useful for possible future testing.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The following conclusions may be drawn from the program:

1) **ICEBREAKING.** That the ACIB will break ice satisfactorily was very clearly demonstrated and, although 66 cm was about the maximum thickness encountered during the trials, there is no reason to doubt that ice up to 1 m in thickness can be broken.

Additionally, it was shown that considerable economies can be achieved because of the rate at which ice is broken and the reduction in propulsion power. Use of the ACIB with the ALEXANDER HENRY eliminated any necessity for ramming, and ice contacts with the propellers were much less frequent and severe, thus reducing hull damage and strain on the propulsion system, additional major economies.

However, the greatest opportunity for saving lies in the potential to operate the ACIB with a smaller, more economical vessel, such a a tug. Operation with the tug THUNDER CAPE was most impressive and a clear indicator of the possibilities. The charter cost was $500.00 per hour on an as required basis.

It is quite possible that another season of operation will demonstrate that the ACIB/small vessel combination is capable of performing efficient ice management without any backup, and that trials in other areas are desirable. Too much emphasis should not be placed on reliability at this stage of assessing the ACIB, because the improved performance offsets a considerable amount of down-time, and the potential cost of repairs will be more than offset by eliminating the necessity to have a conventional icebreaker operating for a very much longer period.

2) **SERVICEABILITY.** Although a number of problems were encountered, notably with skirt segment sole plates, the hydraulic system and the fan clutches, it is considered that effective solutions can be applied to all the unsatisfactory conditions which have been encountered.

In point of fact, there was no time during the operational trials when the ACIB could not have been made available when required. Provided that the ACIB is handled with care when going astern, it may well be that the sole plates on the forward segments are not essential.

The Project Team is confident that a craft can be provided for the 1983/84 season which should be much easier to operate and virtually trouble-free.

3) **COST.** The cost of the program was of great concern to the Project Team because of the late start and the urgency of getting the maximum possible icebreaking time during what was evidently going to be a short season.

It cannot be over-emphasized that maintenance on a piecemeal, firefighting basis is both unsatisfactory and costly. Unplanned work performed at short notice and against a short deadline is seldom more than adequate, and is likely to require repeating when time permits. This happened a number of times.

On the other hand, it appears that the objectives of the program were met, and that the customer was satisfied in terms of results and cost.

Nevertheless, it must be concluded that cost could have been reduced had a longer lead time been given.

4) **SUMMARY**

- o The icebreaking capability of the ACIB was clearly demonstrated.
- o The potential economies of air cushion icebreaking for the port of appear were shown to be substantial.
- o No problems were encountered during the trials which cannot be reduced or eliminated.
- o Satisfactory operational performance can be expected from the ACIB during the 1983/84 season.
- o An early start must be made to prepare for the 1983/84 season, so that all work can be complete by the end of October.

4.2 RECOMMENDATIONS

The following recommendations are made as a result of the program:

- o That the deficiencies in the components and systems of the ACIB, which became apparent during the 1982/83 trials, should be rectified, and the craft certified for operational use during the 1983/84 season.
- o That serious consideration be given to operating the ACIB with a tug or other small vessel during the 1983/84 season, with the ALEXANDER HENRY as backup to be used only in case of inability of the ACIB/small ship to handle the ice management requirement alone or a requirement for higher propulsion power.
- o That, since it seems clear from trial results to date that the ACIB is a useful and efficient accessory for use on the Great Lakes and has the potential to reduce significantly the cost of icebreaking operations in districts such as Thunder Bay, a design for a second generation ACIB should be initiated at an early date. This new design should incorporate any features seen to require investigation as a result of an Arctic Class ACIB study and model tests.

5.0 PROPOSAL FOR FOLLOW-ON PROGRAM

The ACIB trials have shown that the craft does not appear to have any technical or operational characteristics which could prevent certification and introduction into operational service for the 1983/84 season. The following program is proposed:

1.	Preparation of "as built" drawings	May-June
2.	Design and definition of required modifications and repairs	June-July
3.	Request for proposals for required work	July
4.	Award contracts and carry out modifications and repairs	August-October
5.	Check out, certification tests and hand over to CCG	November
6.	Operational use with CCG or merchant ship	November-April

The time schedule for this program is very tight. A new contract must be placed quickly in order to provide management services and supervision for the modifications, repairs and certification, and for assistance in the operational employment of the ACIB, if required.

The work required on the ACIB follows. This has been broken down into three categories as indicated. Items requiring special consideration for certification are marked with an asterisk.

A) ESSENTIAL BEFORE CERTIFICATION AND HAND OVER

		$K
1.	Provision of "as fitted" drawings.* (to be delivered after trials)	15
2.	Provision of operating/maintenance manuals.*	5
3.	Acceptance of fire extinguishing arrangements.*	2
4.	Hydraulic system redesign.*	38
5.	Marking, identification and protection of controls.*	1
6.	Relocate access ladder to centre line.	2
7.	Modify transit winches for 1 in. cable, and supply 500 ft. per winch.	10
8.	Fit 4 Port Colborne fairleads.	4
9.	Weld all deck seams.	10
10.	Electrical system redesign (110/220 VAC)	30
11.	Complete pneumatic system	2
12.	Provide guards on transmission universal joints.	1
13.	Repair carousel	1
14.	Modify and repair skirt segments.	38
15.	Extend wear apron.	5
16.	Provide 2 new notch segments (Nos. 4 and 5)	30
17.	Painting	6
	TOTAL	200

B) STRONGLY RECOMMENDED FOR IMPROVED SAFETY AND HANDLING

1.	Revised instrumentation and control (engines)	5
2.	Liquid ballast system/increased fuel tankage (flotation tanks)	30
3.	Liquid trim system/increased fuel tankage (new under deck tanks)	20
	TOTAL	55

C) DESIRABLE

1.	New Control Room/store room/workshop structure	16
2.	Canvas enclosure for forward area of deck	49
3.	Liquid ballast system - water tanks	35
	TOTAL	**100**

Consideration must also be given to the shore facilities for handling the ACIB. Items required are as follows. These have not been costed.

1. Grading of ramp to prevent pools of water forming.
2. Bollards or mooring rings for handling ACV onto and off ramp.
3. Markers for alignment of ACV on ramp and over platform.
4. Relocation of concrete platform to permit minimum hover height beaching.
5. Maintenance building (workshop and crew facilities).
6. Storage space (preferably heated and with enough room to do skirt repairs).

Canadian Coast Guard has estimate that two person years are required for operation and maintenance. We would qualify this statement to relate to routine maintenance (servicing) and minor repairs, and agree on the following basis:

Deck Officer	Nov. to April	Six months
Engineer Officer	Nov. to April	Six months
Technician (Mechanical/Electrical)		One year

Major maintenance and repairs should be carried out either by support from other CCG resources or by local contracts. Rather than establish a CCG maintenance facility at this time, the latter is recommended, with standing offer contracts (fixed rates) negotiated before each season. Minimal spares should be held, special note being taken of local sources, of items not available locally and of long lead time items. The following is a suggestion for 1983/84 support, assuming that tools and clothing are available:

			$K
1.	Spare skirt segments -	Straight 4	32
		Curved 2	16
		Notch 1	16
2.	Spare skirt material		16
3.	500 h inspection of diesels		5
4.	Standing offer contracts for goods and services		
		Mechancial	10
		Electrical	10
		Rubber work	10
	TOTAL		115

APPENDIX "A"

INSTALLATION OF RPM MONITORING SYSTEM

ACIB - 1982/83

german & milne inc.

4999 ouest, rue Ste-Catherine Street West, Suite 300
Montréal, Québec, Canada H3Z 1T3
Téléphone: (514) 487-0701 Telex: 055-66413 GERMIL, MTL
Câble: "VALVE"

THUNDER BAY TRIP REPORT
INSTALLATION OF RPM
MONITORING SYSTEM

IMPLEMENTATION AND MANAGEMENT OF THE
1982/83 EVALUATION OF THE
AIR CUSHION ICEBREAKER BOW (ACIB)

DSS CONTRACT NO. OSD82-00128

AUTHOR: A. Benjamin

DATE: March 4, 1983

REPORT NO: 7027-R05

THUNDER BAY TRIP REPORT - W.O. 7027

INSTALLATION OF RPM - MONITORING SYSTEM

The installation of the RPM Monitoring System on the Canadian Coast Guard ship Alexander Henry was carried out on February 23rd to 25th, 1983. The system monitors the engine and shaft RPM of both port and starboard propulsion systems, and displays the information on a CRT screen.

All equipment shipped was set-up and tested in the on-site trailer and was found to be in proper working condition.

1.0 INSTALLATION

The CCGS Alexander Henry was visited on Wednesday p.m. with Mr. J. Tarzwell.

Persons contacted:

Captain J. MacDonald

Chief Engineer Williams

The engine room was inspected to decide upon a suitable location for the installation of the RPM Monitoring System. On consultation with the ship's 1st Engineer, it was decided that the thruster spaces were most appropriate, as this area was less frequented by operating personnel when the ship was in motion.

Further, the 2nd Engineer reports that the engine and shaft tachometers had been calibrated using a stroboscope early in February by Vulcan Ltd. engineers. The meter readings were hence not re-calibrated and assumed to be accurate for the purpose of deriving conversion equations.

The wiring installation was carried out by tapping the four inputs to the four tachometers on the engine room control console. 115V power was obtained from an outlet near the control console. The wires were routed along existing wire-trays back to the thruster spaces as shown in Figure 1.

2.0 SOFTWARE

In discussions with Mr. Tarzwell, he indicated his preference for the strip-chart output as the most convenient for subsequent analysis.

The final version of the software was then developed to display port and starboard engine RPM and the differences between engine and shaft RPM on each side. Further, all port side information is offset by a predetermined amount. This scheme alleviates the problem of overlap of the four plots, and in most operating conditions will give four distinct plots. Conversion equations and sampling rates are shown in Figure 2.

3.0 CALIBRATION AND TESTING

As the ship was tied up, the calibration and testing of one engine at a time was carried out.

PORT CALIBRATION

ERPM	volts	SRPM	volts
0	0	0	0
135	2.98	100	1.68
170	3.91	150	2.63
215	4.97	195	3.43

ERPM constant = 43.37 RPM/volt

SRPM constant = 56.94 RPM/volt

STARBOARD CALIBRATION

ERPM	volts	SRPM	volts
130	3.13	110	1.4
160	3.85	145	2.72
215	5.18	200	3.69

ERPM constant = 41.53 RPM/volt

SRPM constant = 53.75 RPM/volt

The printout obtained from the testing of the system is shown in Figure 3.

Note that due to problems with the hydraulic coupling on the starboard engine, the RPM fluctuates considerably. Also, differences in RPM are larger at lower speeds. At full ahead ERPM = 260 and SRPM = 250.

4.0 OPERATION

A Power:

Switch on power to 3497A

B Enter Date:

Push <Timer Date> button

Enter date and time <MMDDHHMMSS>e.g. at 4.18 p.m. on 24th February enter 0224161800

Push <Execute>

To verify correct entry has been made

Push <Timer Date> then <Execute>

The right time will be displayed and updated every second

The 3497A is now ready for operation to give the HP85 all required data

C Insert Tape:

Insert tape marked "DATA 1" into HP85 tape slot and push until you hear a distinct click.

D Power:

Turn on power switch at the back of the HP85 on the right hand side.

The computer will automatically load the program from tape and commence operation. (It can take upto two minutes before the first information is displayed on the screen).

The computer will progressively display the RPM in strip chart format on the screen. When the screen is full a hard copy of the screen is made by the printer (similar to figure 3) before the screen is cleared for a new plot.

E Plot Scale:

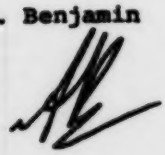
The plot currently produced (slightly different from figure 3) has a full scale range of 0-8V corresponding to 0-350 RPM. All port side information is plotted with an offset of 2V or 87.5 RPM.

F Halt:

Push <K8> button (shift K4) to stop recording.

Note that the system has an automatic restart feature should power down occur while recording. However, the time stored in the 3497A memory is lost and must be re-entered.

A. Benjamin



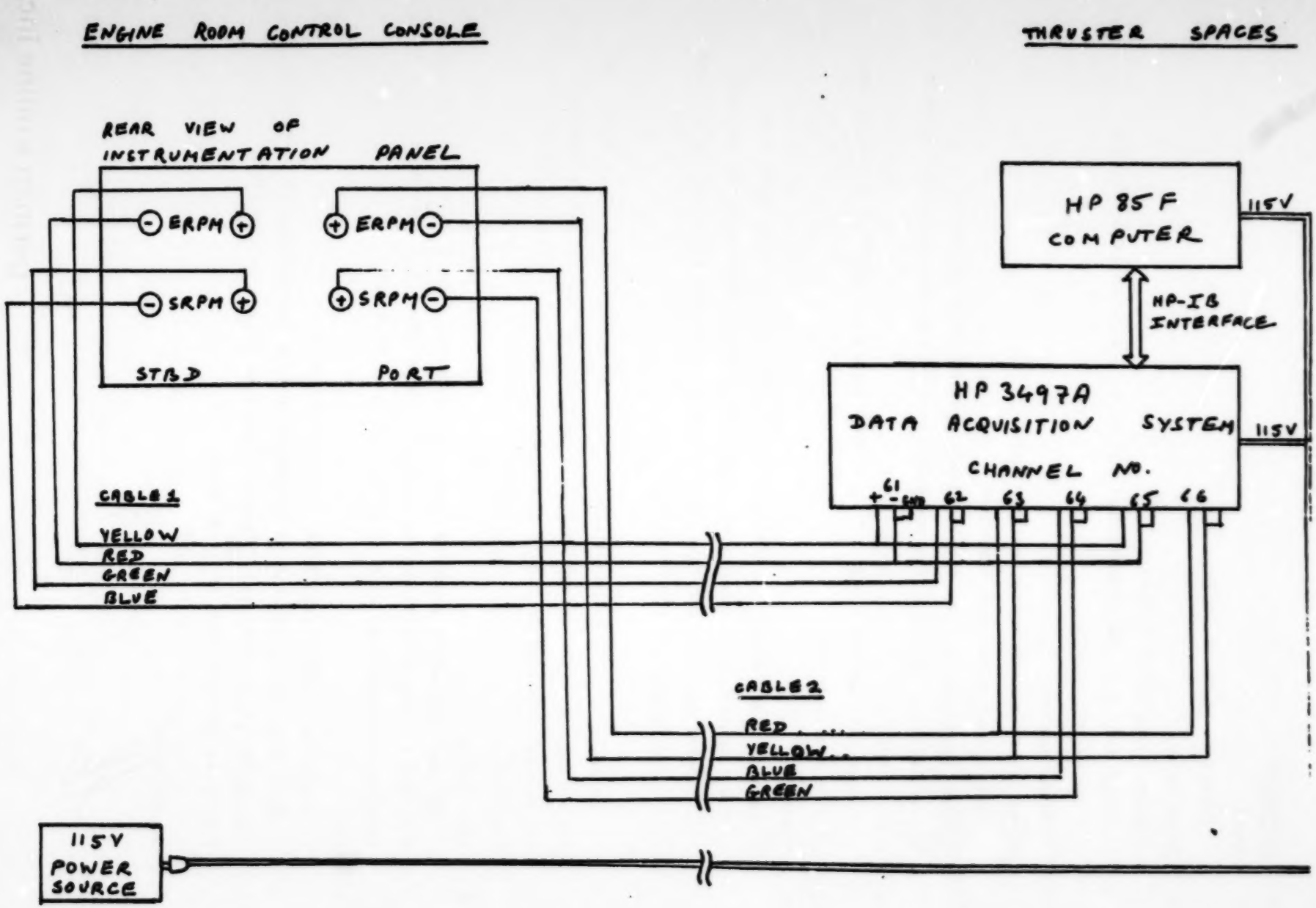
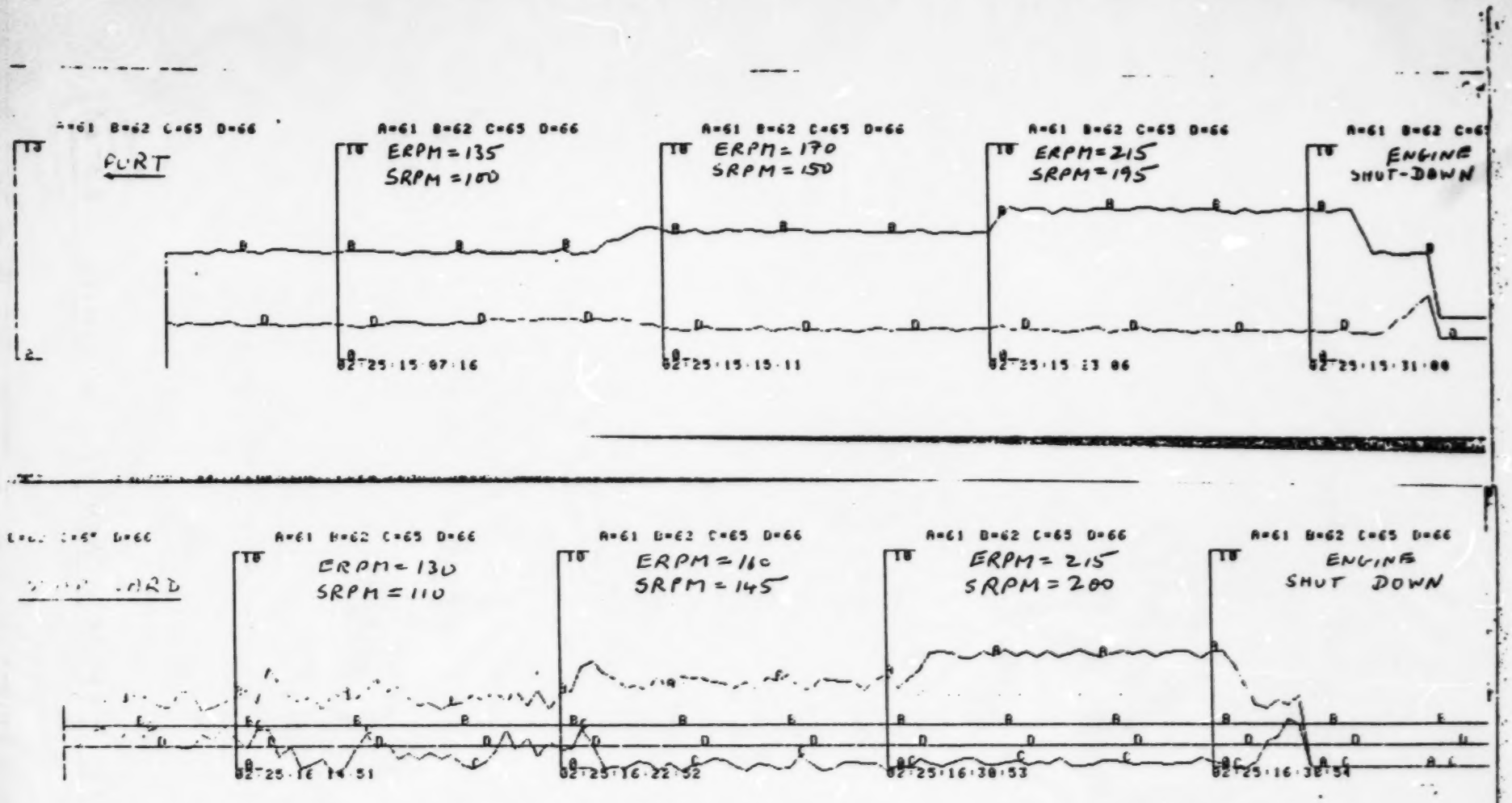


FIG 1: WIRING INSTALLATION DIAGRAM

```
---DATA LOGGER CHANNEL SETUP---

CHANNELS:
          061
FUNCTION: 10V
LABEL:    ERPMS
         =0+1X

CHANNELS:
          062
FUNCTION: 10V
LABEL:    ERPMP
         =2+1X

CHANNELS:
          063
FUNCTION: 10V
LABEL:    SRPMS
         =0+1.28X

CHANNELS:
          064
FUNCTION: 10V
LABEL:    SRPMP
         =-2+1.29X

CHANNELS:
          065
FUNCTION: 10V
LABEL:    DRPMS
         =X-CH63

CHANNELS:
          066
FUNCTION: 10V
LABEL:    DRPMP
         =X-CH64

--------------------------------


----DATA LOGGER TIMING SETUP----

TIMING SETUP SAVED---TIMING

RECORD OFF
PRINT OFF
STRIP 61,62,65,66
SCALE 0,8,60
START ALEX1
WAIT 00:01
REPEAT 2

--------------------------------
```

FIG 2: DATA LOGGER CHANNEL & TIMING SETUP



A = CH61 : STBD ERPM

B = CH62 : PORT ERPM offset = 2

C = CH65 : STBD (ERPM − SRPM)

D = CH66 : PORT (ERPM − SRPM) offset = 1

FIG 3: SYSTEM PRINTOUT DURING TEST

APPENDIX "B"

INVESTIGATION OF BOND FAILURES

ACIB - 1982/83

german & milne inc.

4999 ouest, rue Ste-Catherine Street West, Suite 300
Montréal, Québec, Canada H3Z 1T3
Téléphone: (514) 487-0701 Telex: 055-66413 GERMIL, MTL
Câble: "VALVE"

ACIB Project,
Thunder Bay, Ontario.

March 24, 1983.

Mr. Michael T. Skinner,
Manager,
REMATECH Industries,
370 Mooney Street,
Thunder Bay, Ontario.
P7B 5R4

Dear Mr. Skinner:

As you are aware, extensive damage to the skirt sole pieces of the Air Cushion Icebreaker Bow (ACIB) occurred during the recent operational trials with the craft notched to the Alexander Henry. As a consequence of this damage, it was necessary to declare the ACIB non-operational and to beach it for inspection and a subsequent decision on its further use this season. As the Alexander Henry had completed the major portion of its planned icebreaking work with the ACIB, the decision was made to terminate this season's ACIB operational trials. Before the ACIB can be made ready for operational use next year, modifications to the method of attachment of sole pieces to the skirt segments will have to be made and possibly new materials employed. Before such work can be undertaken, it is essential that the cause of failure of the current skirt/sole attachment method be established.

Prior to subcontracting with your company for the skirt modifications we were given to understand that the bonded joints would be as strong as the host material. This has not been the case. Our inspection has revealed that virtually all of the failures can be attributed to the separation of bonded joints. In most cases the progressive separation of the bonds appears to have commenced with the working loose of the finger-like curved bonding section at the juncture of the outboard end of the sole and the bottom of the skirt proper. The separation then progresses inboard along one or both sides of the sole/skirt bonded joint. The separation ranges from a few inches on one side of the sole through to total separation on both sides. This is most unsatisfactory and would not be acceptable for future work.

Cont'd.

It is, however, significant to note that 19 of the skirt/sole segments are essentially intact. This includes the five that were recently modified. From this we can conclude that skirt/sole segments with durable bonded joints can survive for at least 30 hours of icebreaking operations and possibly several times that duration. This would be an operationally useful lifespan for these components.

It is, therefore, requested that you investigate the failure of the bonded joints to determine the cause and the changes in materials and/or procedures that should be made to ensure that bonded joints with the required strength can be made employing your procedures and materials. We would appreciate receiving a report on your findings and recommendations as soon as possible, since these will undoubtedly have a bearing on the plans for the future of the craft.

My Company and I are prepared to assist you in any way we can in the conduct of your investigation.

Yours sincerely,

J. A. Tarzwell,
ACIB Trials Manager.

JAT/sj

c.c. J. Leddy,
Vulcan Machinery,
Thunder Bay, Ont.

P. Markham,
German & Milne,
Ottawa, Ontario.

REMATECH

REMATECH INDUSTRIES
DIVISION OF
RUBBERTEX CORPORATION LTD.
370 MOONEY ST.
THUNDER BAY, ONT. P7B 5M4
TELEX 073 4889
TEL. 807-345-2549

German and Milne In.
4999 West, Rue Ste. Catherine St. W.,
Suite 300
Montreal, Quebec
Canada
H3Z 1T3

April 22, 1983

Att: Mr. J. A. Tarzwell - ACIB Trials Manager

Re: your Letter of March 24, 1983

Dear Mr. Tarzwell:

As per our discussion prior to your leaving Thunder Bay, we have conducted a full investigation into the causes of such poor adhesion. This we had to coincide with tests done in our shop trying to duplicate the same working condition.

Our findings were as follows:
After 1 hour of curing time with 1" wide by 2" overlap samples being completed on the table and floor, adhesion strength was 5 lbs. tensil strength 310 lbs. With a 4" overlap our adhesion was the same but the tensile strength was 460 lbs.

After 3 hours of curing time on the 1" wide strip with a 2" overlap, our adhesion strength was 25 lbs., and our tensile strength was 450 lbs. With a 4" overlap adhesion was the same but the tensile rating was over 500 lbs. (our guage goes only to 500 lbs.)

After 36 hours of curing time, our 1" strip with a 2" overlap had a 60 lb. adhesion and the tensil rating was over 500 Lbs.

We found very little difference between tests done on the floor and the test done on the work bench. Further tests were done with material having 3 hours of curing time with an adhesion factor of 25 lbs. and then placed in the freezer and left for 4 days. Upon taking these samples out and immediately doing adhesions tests, we found we would get no more than 23 lbs on any of these samples. After sitting in a warm environment for 24 hours, we then had an adhesion factor of 40 lbs.

All of the above tests were done using 10 samples for each test and taking an average.

It must be noted that to achieve acceptable adhesion at least 36 hours of curing time is required.

When most of the repairs or modifications were being done very little curing time was allowed. Also, with such a rush job being done I feel the workmanship also left something to be desired. The combination of these two factors is what I believe to have been the cause of the poor bonds mentioned in your letter.

Further tests have been done using a hot vulcanizing process with 75 lbs. pressure and adhesion tests show an adhesion strength of 120 lbs.*

Samples of this can be shipped to you for your inspection at your request.

I hope that with the results of the tests we have conducted that this will answer your questions.

If any further tests need be done, please feel free to call on us.

Yours very truly

M. T. Skinner
Manager

* This was a Goodyear process using NYLO-BOND cement and TIEGUM. Sample was cured for 15 m at 290°F.

Ciment SC 2000
Pour le collage du caoutchouc sur métal, toile sur métal, caoutchouc sur caoutchouc, toile sur toile.

Brossage:
● Brosser la toile avec la brosse rotative de sorte et enlever la poussière à sec. ● Brosser le caoutchouc avec la brosse rotative de sorte qu'il n'y ait plus des traces de couteau, et des parties brillantes. ● Enlever la poussière à sec. ● La surface métallique doit être exempte de saleté et de rouille par sablage. Ensuite laver au solvant nettoyant TIP TOP.

Mélange:
● Mélanger bien le ciment SC 2000 avec 10% durcisseur RF. Important: Le mélange doit être utilisé dans les 2 heures au maximum.

Enduction:
● Enduire métal, caoutchouc et toile de 2 couches de SC 2000 additionnées de 10% de durcisseur RF.

Séchage:
● Laisser bien sécher la 1re couche sur caoutchouc et toile - sur métal, temps de séchage minimum 1 à 2 heures. Cette couche doit être encore en «humeur» (effectuer le contrôle avec le dos des doigts). En cas de surséchage de cette seconde couche en passer une troisième.

Molétage:
● Placer le revêtement sans imprisonner de bulles d'air et molster fortement.

Cement SC 2000
For bonding rubber to metal, fabric to metal, rubber to rubber, fabric to fabric, rubber to fabric.

Buffing:
● Buff canvas with rotating wire brush and remove buffing dust by dry brush. ● Buff rubber with wire brush until all grooves, cuts and glossy spots have disappeared. ● Remove buffing dust by dry brush. ● Remove dirt and rust from metal to be covered by sandblasting. Then wash treated metal surface with REMA TIP TOP cleaning solvent.

Mixing:
● Mix well cement SC 2000 with approximately 10% RF hardener. Note: The mixture SC 2000 hardener must be used within 2 hours.

Coating:
● 2 coats of SC 2000 plus hardener have to be applied to metal, rubber and canvas.

Drying:
● Allow first coat applied to rubber and canvas to dry well — minimum drying time on metal 1-2 hours. 2nd coat, however, let dry only until slightly tacky to back of finger. In case of overdrying apply 3rd coat.

Stitching on:
● Stitch on vigorously rubber covered area.

APPENDIX "C"

AIR CUSHION ICEBREAKING BOW

HSL533

TEST PLAN
1982/83

ACIB HSL533 - TEST PLAN 1982/83

OBJECTIVES

TESTS OF THE CANADIAN COAST GUARD AIR CUSHION ICEBREAKING BOW (ACIB) WILL BE CONDUCTED AT THUNDER BAY DURING THE PERIOD 15 JANUARY TO 15 APRIL 1983. THE TUG THUNDER CAPE AND THE CCGS ALEXANDER HENRY WILL BE USED FOR THESE TESTS, WHICH WILL BE MANAGED BY GERMAN & MILNE INC. THE OBJECTIVES GIVEN IN THE WORK STATEMENT ARE AS FOLLOWS:

OVERALL OBJECTIVE

TO IMPROVE THE OVERALL EFFECTIVENESS OF ICE-BREAKING OPERATIONS IN INLAND AND COASTAL WATERS THROUGH THE DEVELOPMENT OF AN ACIB, AND TO EXTEND ACIB TECHNOLOGY FOR USE IN THE ARCTIC.

SPECIFIC OBJECTIVES

TO EXPLORE AND DEFINE, IN QUANTITATIVE TERMS, THE PERFORMANCE PARAMETERS OF THE ACIB, AND
TO GAIN OPERATIONAL EXPERIENCE WITH THE ACIB TO THE GREATEST EXTEND PRACTICAL DURING THE 1982/83 WINTER SEASON.

ACIB STATUS

TESTS LATE IN THE 1981/82 SEASON REVEALED A NUMBER OF DEFICIENCIES WHICH AFFECTED OPERATION AND SAFETY. THE ITEMS CONSIDERED ESSENTIAL TO ENSURING SERVICEABILITY AND SAFETY THROUGH THE 1982/83 SEASON WILL BE RECTIFIED BY EXTENSIVE MODIFICATIONS AND REPAIRS. LESS IMPORTANT ITEMS HAVE BEEN DEFERRED.

IF THE 1982/83 WINTER SEASON TESTS ARE SUCCESSFUL, SEVERAL OTHER CHANGES WILL BE REQUIRED, AND SHOULD BE INCORPORATED DURING THE SUMMER OF 1983.

INSTRUMENTATION

MEASUREMENT OF PERFORMANCE PARAMETERS IS BEING INTERPRETED IN ITS BROADEST SENSE, AND ONLY THE FOLLOWING WILL BE CONSIDERED TO BE ESSENTIAL INFORMATION:

- SPEED* - TO BE MEASURED WITH VIDEO EQUIPMENT
- SHAFT RPM* (SHIP) - SHIP'S INSTRUMENTATION AND G&M INSTRUMENTATION
- WEIGHT (ACIB) - TO BE ESTIMATED
- ENGINE/FAN RPM* (ACIB) INSTRUMENTATION
- CUSHION PRESSURE* (ACIB) - TUBE MANOMETER AND DIAL MANOMETER
- DECK ELEVATION (ABIC) - TAPES

THE FOLLOWING PARAMETERS WILL ALSO BE MEASURED:

- ENGINE RPM (SHIP) - SHIP'S INSTRUMENTATION AND G&M INSTRUMENTATION
- TRIM - INCLINOMETER
- FUEL CONSUMPTION - FLOW INDICATORS (SHIP) AND DIRECT MEASUREMENT

THE FOLLOWING MAY BE MEASURED:

- THRUST (SHIP) - LOAD CELLS, IF SERVICEABLE
- TORQUE AND TORQUE EXCURSION (SHIP) - TORQUEMETERS, IF AVAILABLE

OPERATIONAL USE WILL ONLY BE RESTRICTED IF ESSENTAIL* INSTRUMENTATION IS UNSERVICEABLE.

ENVIRONMENTAL MEASUREMENTS

THE FOLLOWING INFORMATION IS REQUIRED:

- ICE THICKNESS - BY DIRECT MEASUREMENT
- SIZE OF ICE PIECES - BY DIRECT MEASUREMENT
- TRACK WIDTH - BY DIRECT MEASUREMENT
- WATER TEMPERATURE - BY DIRECT MEASUREMENT
- AIR TEMPERATURE - FROM SHIP'S INSTRUMENTATION
- WIND VELOCITY - FROM SHIP'S INSTRUMENTATION
- WIND DIRECTION - FROM SHIP'S INSTRUMENTATION
- RELATIVE HUMIDITY - FROM SHIP'S INSTRUMENTATION

OTHER MEASUREMENTS

TURNING CIRCLES WILL BE MEASURED AND TRACK WIDTH CHECKED BY SIMPLE AERIAL PHOTOGRAPHY. AN AIRCRAFT WILL BE OBTAINED FROM THE THUNDER BAY FLYING CLUB.

IF POSSIBLE, A CINÉ OR VIDEO RECORD WILL BE MADE OF THE ICEBREAKING OPERATION USING A HELICOPTER.

TEST SERIES 1 - ACIB CHECKOUT

OBJECTIVES

- TO VERIFY THE INTEGRITY AND EFFECTIVENESS OF MODIFICATIONS AND REPAIRS
- TO CHECK OUT AND CALIBRATE TEST INSTRUMENTS
- TO CONFIRM SYSTEM PERFORMANCE

TEST 1A - ACIB CHECKOUT OVER LAND

PROCEDURE:

THE ACIB WILL BE OPERATED IN A TETHERED CONDITION. TRIM BALLAST ONLY.
FUNCTIONAL CHECKS OF ALL SYSTEMS WILL BE PERFORMED, PAYING PARTICULAR ATTENTION TO:

- ADEQUACY OF COMMUNICATING SYSTEM
- WARMTH AND SOUNDPROOFING OF CONTROL ROOM
- DECK AND OTHER AIR LEAKS
- INFLATED CONFIGURATION OF THE NOTCH SEGMENTS, SPRAY SKIRT AND RUBBING APRONS
- WINCH OPERATION, AND FLEXIBILITY OF NEW CABLES
- ADEQUACY OF FAN PROTECTION (SCREEN AND SHIELDS)
- EFFECTIVENESS AND OPERATION OF BALLAST TANKS

MEASUREMENTS:

WEIGHT
HOVER HEIGHT AND CUSHION PRESSURE VERSUS ENGINE RPM

WARNING: ALL TESTING TO BE CONDUCTED BELOW ONSET OF HEAVE INSTABILITY.

POST-TEST INSPECTION:

INSPECT PARTICULARLY ALL SKIRT SEGMENTS, THE SPRAY SKIRT AND RUBBING APRONS, TOGETHER WITH ALL ATTACHMENTS AND SUPPORT BEAMS. REPAIR AND/OR MODIFY AS REQUIRED.

NOTE: INCIPIENT PROBLEMS WHICH MIGHT LEAD TO MAJOR DIFFICULTIES AND DELAYS LATER IN THE PROGRAM ARE THE OBJECTIVES OF THIS INSPECTION.

TEST 1B - ACIB CHECKOUT OVER WATER - LIGHT

PROCEDURE:

TRIM BALLAST ONLY.
THE ACIB WILL BE MOVED FROM ITS LAND LOCATION TO A POSITION ON THE CCG DOCK. IT WILL BE AN EXERCISE IN HANDLING THE ACIB WITH WINCHES, AND WILL PROVIDE A MORE REALISTIC SITUATION FOR ASSESSING AIR LEAKS.

MEASUREMENTS:

HOVER HEIGHT AND CUSHION PRESSURE VERSUS ENGINE RPM.

TEST 1C - INITIAL NOTCHING - SHIP STATIONARY

PROCEDURE:

NOTCH ACIB WITH ALEXANDER HENRY.
CHECK FOR STRAIN ON THE NOTCH BOOMS AND FOR DISTORTION OF THE NOTCH SEGMENTS, SPRAY SKIRTS AND RUBBING APRONS WHEN COMING UP ON CUSHION AND DESCENDING FROM CUSHION.
CHECK NOTCH SEALING.
PERFROM FUNCTIONAL TESTS OF ALL SYSTEMS AND INSTRUMENTATION ON ACIB AND SHIP. CHECK ACIB/SHIP COMMUNICATIONS PARTICULARLY.

MEASUREMENTS:

HOVER HEIGHT AND CUSHION PRESSURE VERSUS ENGINE RPM.
NOTE TRIM REQUIRED.

TEST 1D - ACIB CHECKOUT OVER WATER - BALLASTED

PROCEDURE:

BALLAST TO MAXIMUM AUTHORIZED ALL UP WEIGHT (260T)

NOTE: ALL FURTHER TESTS WILL BE CARRIED OUT AT THIS WEIGHT, AND IT IS NOT INTENDED TO REMOVE ANY BALLAST BLOCKS UNTIL THE 1972/73 TRIALS ARE COMPLETED.

MEASUREMENTS:

FREEBOARD VERSUS WEIGHT WHILE BALLASTING.
HOVER HEIGHT AND CUSHION PRESSURE VERSUS ENGINE RPM ONE ONE, TWO AND THREE ENGINES.

TEST 1E - FUNCTIONAL TESTS - SHIP IN MOTION

PROCEDURE:

SHORT SHAKEDOWN OF ACIB/ALEXANDER HENRY COMBINATION AT SPEEDS UP TO THE MAXIMUM ATTAINABLE UNDER ENGINE LIMITS SPECIFIED. PERFORM FUNCTIONAL TESTS OF ALL SYSTEMS AND INSTRUMENTATION.

MEASUREMENTS:

ANY ANGULAR CHANGE OF TRIM AS VELOCITY INCREASES IS TO BE MEASURED, AND BALLAST REQUIRED TO RESTORE TRIM NOTED.

NOTE: SPEED WILL BE INCREASED IN SMALL STEPS, SAY 0.5 M/S OR 1 KNOT INCREMENTS, AND DISCONTINUED IMMEDIATELY IF ANY PROBLEM OCCURS WITH HANDLING, STABILITY OR SERVICEABILITY OF THE ACIB.

READINGS FROM ALL APPROPRIATE ACIB AND SHIP INSTRUMENTATION ARE TO BE OBTAINED AND RECORDED, AS WELL AS THE METEOROLOGICAL AND ICE CONDITIONS.

TEST SERIES 2 - SMALL VESSEL TESTS

OBJECTIVES:

- To demonstrate ACIB operation with a small, non-icebreaking vessel.
- To measure width of ice broken by the ACIB.

PROCEDURE:

The tug THUNDER CAPE will be modified by removing the rubber tire fenders normally used, and fairing in the strake and cable eyes for approximately 8m from the stem. This should permit notching to be carried out without fouling between the tug and the rubbing aprons.
The video speed measuring equipment will be installed in the THUNDER CAPE.
After notching, the fit will be checked at rest and under way. Testing will not proceed unless it is reasonably certain that further operation will not cause damage. Only if the situation is satisfactory, or when an unsatisfactory condition can be rectified, will the test continue.
The ACIB/THUNDER CAPE combination will be operated in ice at speeds up to the maximum attainable.

NOTE: Speed will be increased in small steps, say 0.5 m/s or k knot increments, and discontinued immediately if any problem occurs with handling, stability or serviceability of the ACIB.

MEASUREMENTS:

ENGINE RPM (TUG)
VELOCITY
ACIB PARAMETERS
METEOROLOGICAL AND ICE CONDITIONS

POST-TEST INSPECTION:

DENOTCH AND INSPECT CONTACT AREAS FOR WEAR OR DAMAGE. REPAIR AND/OR MODIFY AS REQUIRED.

TEST SERIES 3 - ALEXANDER HENRY - ICEBREAKING PERFORMANCE

OBJECTIVES:

- To familiarize the crew of the ALEXANDER HENRY with the ACIB
- To obtain quantitive data on the icebreaking performance of the ship/ACIB combination.

PROCEDURE:

In order to obtain a wide range of ice conditions, this series of tests will be conducted at times during the season which will provide a typical range of ice thickness and strength. It is proposed to seek the following characteristics for runs at nominal ice thicknesses of 30cm, 65cm, 100cm:
- Smooth, snow free ice
- Smooth to ridged ice
- Snow covered ice

65cm of rotting will be sought in the Spring.
Comparisons will be made on the basis of fuel consumption (power), speed, and ice thickness and condition.
Sufficient runs will be made to indicate consistency of measurement, and conditions need not be restricted to those specified above. It is desirable to obtain as many samples as possible.
Turning circles will be measured in each ice condition.

MEASUREMENTS:

Ship and ACIB parameters
Meteorological and ice conditions.

german & milne inc.

POST-TEST INSPECTION:

INSPECTIONS AND PREVENTIVE MAINTENANCE ARE TO BE CARRIED OUT AS OCCASION INDICATES, BUT AT LEAST BETWEEN MISSIONS.

TEST SERIES 4 - ALEXANDER HENRY - OPERATIONAL TRIALS

OBJECTIVES:

- TO USE THE ACIB AS MUCH AS POSSIBLE TO ASSIST IN THE ICE CLEARING TASKS NORMALLY CARRIED OUT IN THE THUNDER BAY AREA.

PROCEDURE:

IT IS HOPED THAT, ONCE THE ALEXANDER HENRY IS NOTCHED WITH THE ACIB FOR TEST SERIES 3, IT WILL NOT BE NECESSARY TO DENOTCH UNLESS SOME SERIOUS UNSERVICEABILITY OCCURS. CONSEQUENTLY THE ACIB SHOULD BE AVAILABLE FOR ANY OPERATIONAL COMMITMENT DURING THE SECOND PHASE OF THE ICE SEASON.
DURING OPERATIONAL TRIALS, THE ACIB WILL BE OPERATED BY CCG PERSONNEL, UNDER THE SUPERVISION OF THE G&M TRIALS MANAGER, AND WITH G&M PERSONNEL TO ASSIST, IF NECESSARY. THE TRIALS MANAGER WILL CONTINUE TO BE RESPONSIBLE TO THE SHIP'S CAPTAIN FOR SAFETY DURING NOTCHING OPERATIONS AND WHEN THE ACIB IS ATTACHED TO THE SHIP.
COMMENTARY AND RECORDS WILL BE KEPT ON SUCH ITEMS AS NOTCHING AND DENOTCHING, LENGTH OF CHANNEL CLEARED OR WIDENED, MANOEUVRING PERFORMANCE, COMMUMINCATIONS, MANNING AND METEOROLOGICAL CONDITIONS.

MEASUREMENTS:

NO MEASUREMENTS ARE REQUIRED DURING THIS SERIES OF TRIALS. HOWEVER, THE TRIALS MANAGER MAY SUPPLEMENT THE RECORDS OBTAINED IN SERIES 1, 2 AND 3, AS HE SEES FIT.

ACIB TEST PLAN 1982/83
PRELIMINARY SCHEDULE

COMPLETE ACIB REPAIRS AND MODIFICATIONS	JAN. 12-83
ACIB CHECK-OUT	
OVERLAND TEST (UNBALLASTED)	JAN. 13-14-83
LAUNCH ACIB	JAN. 17-83
OVER WATER TESTS (UNBALLASTED)	JAN. 17-83
OVER WATER TESTS (BALLASTED TO FULL AUTHORIZED WEIGHT)	JAN. 18-83
STATIC NOTCHING TESTS (A.H. MOORED OFF DOCK)	JAN. 19-20-83
INITIAL PUSHING TESTS WITH ALEXANDER HENRY	JAN. 21-83
ACIB CHECK-OUT COMPLETED	JAN. 21-83
ACIB PERFORMANCE TESTS	
SMALL VESSEL TESTS (WITH THUNDER CAPE)	JAN. 24-28-83
ALEXANDER HENRY ESCORTS TUG AND STANDS BY TO ASSIST DURING TESTS	
FIRST SERIES OF ICE-BREAKING PERFORMANCE TESTS WITH ACIB MATED TO ALEXANDER HENRY	JAN. 31-FEB. 4-83
ALEXANDER HENRY SELF-REFIT	FEB. 7-FEB. 18-83
SECOND SERIES OF ICE-BREAKING PERFORMANCE TESTS WITH ACIB MATED TO ALEXANDER HENRY	FEB. 21-FEB. 25-83
OPERATIONAL TRIALS	FROM FEB. 28-83

POOR

QUALITY

ORIGINAL